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ONCE UPON A TIME, EARTH WAS THE ONLY WATER WORLD. BUT IT MAY TURN OUT TO BE A

## WET UNIVERSE

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# LX200

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7" • 8" 10" • 12"

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With their large object databases, fast slewing speeds, and uncanny pointing precision, Meade LX200's are recommended for those amateurs who intend an extensive program of CCD imaging, astrophotography, or deep-space observing.

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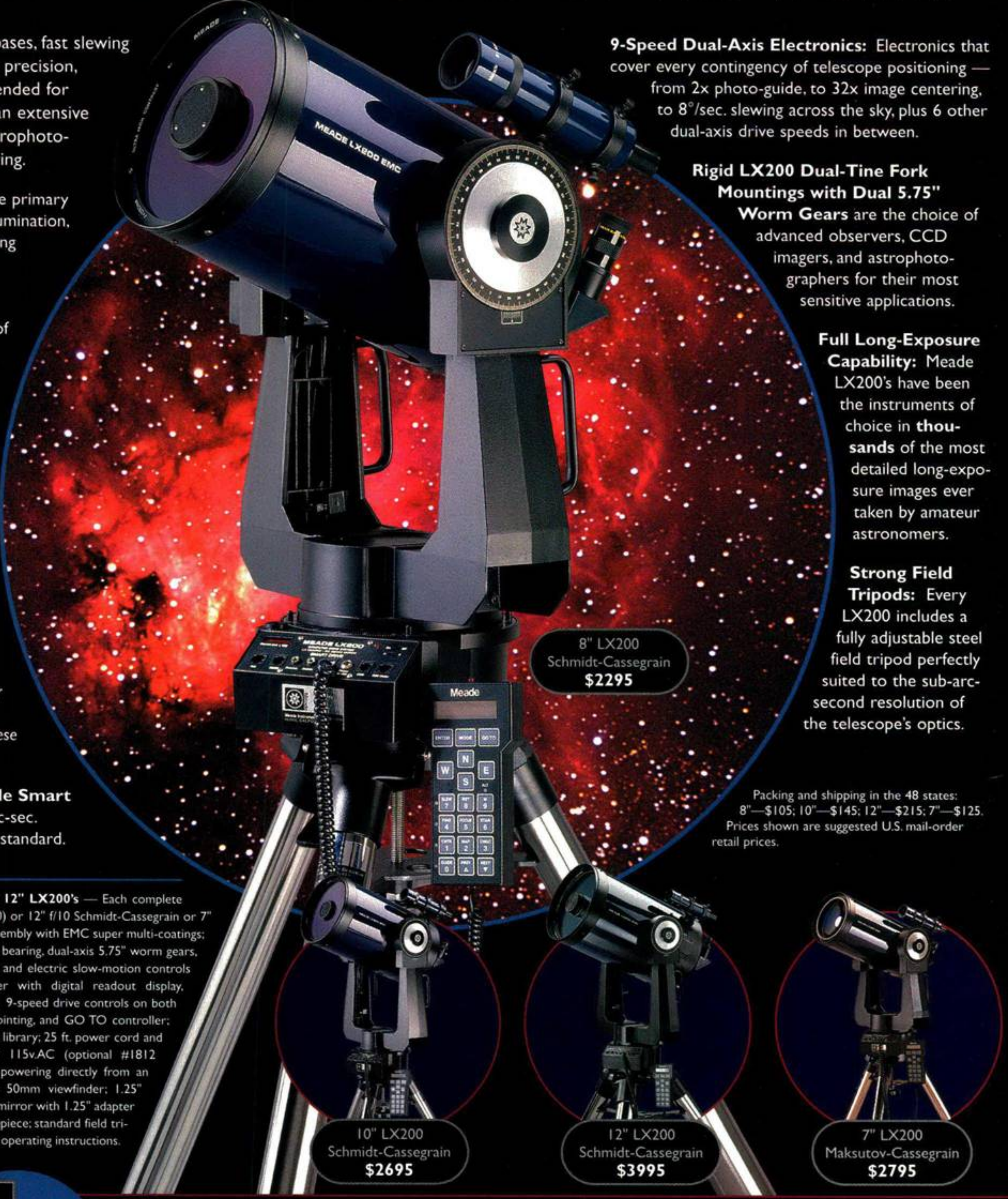

8" LX200
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**$2295**

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Schmidt-Cassegrain
**$3995**

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Maksutov-Cassegrain
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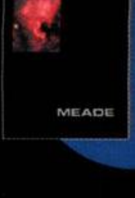
**SPECIFICATIONS: 7", 8", 10", and 12" LX200's** — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.



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**2.** Fax or mail a copy of your dealer's invoice (showing the telescope's serial number) to Meade Instruments/Attn: Customer Service, and request the "Free $600 Eyepiece Offer." *Requests for this special eyepiece offer must be postmarked not later than August 31, 2001, and must include your complete shipping address and phone number.*

**3.** We will ship your free eyepiece package to you within 30 days of our receipt of your request. Meade Instruments will pay for all shipping and insurance charges; safe arrival is guaranteed. This special offer is valid only for new LX200 telescopes ordered and received within the U.S.A.

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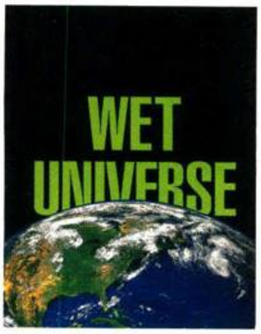

COVER PHOTO: NASA's Goddard Space Flight Center

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From *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

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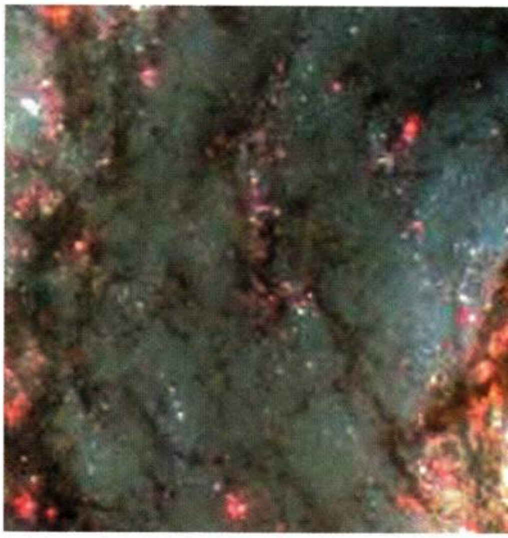
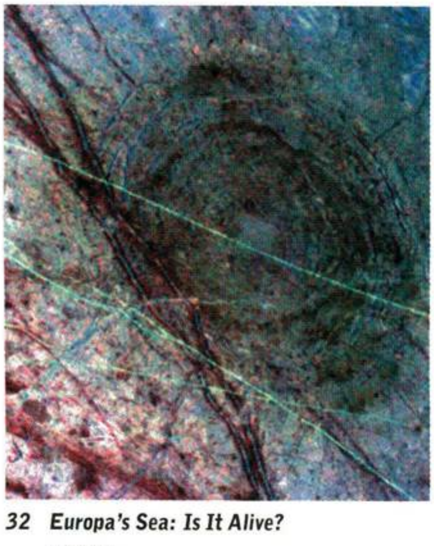
Johns Hopkins University and NASA





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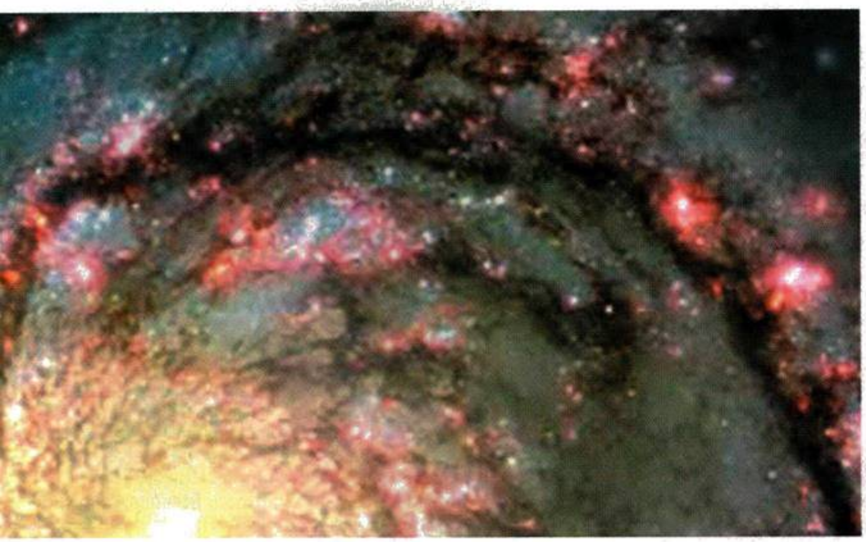

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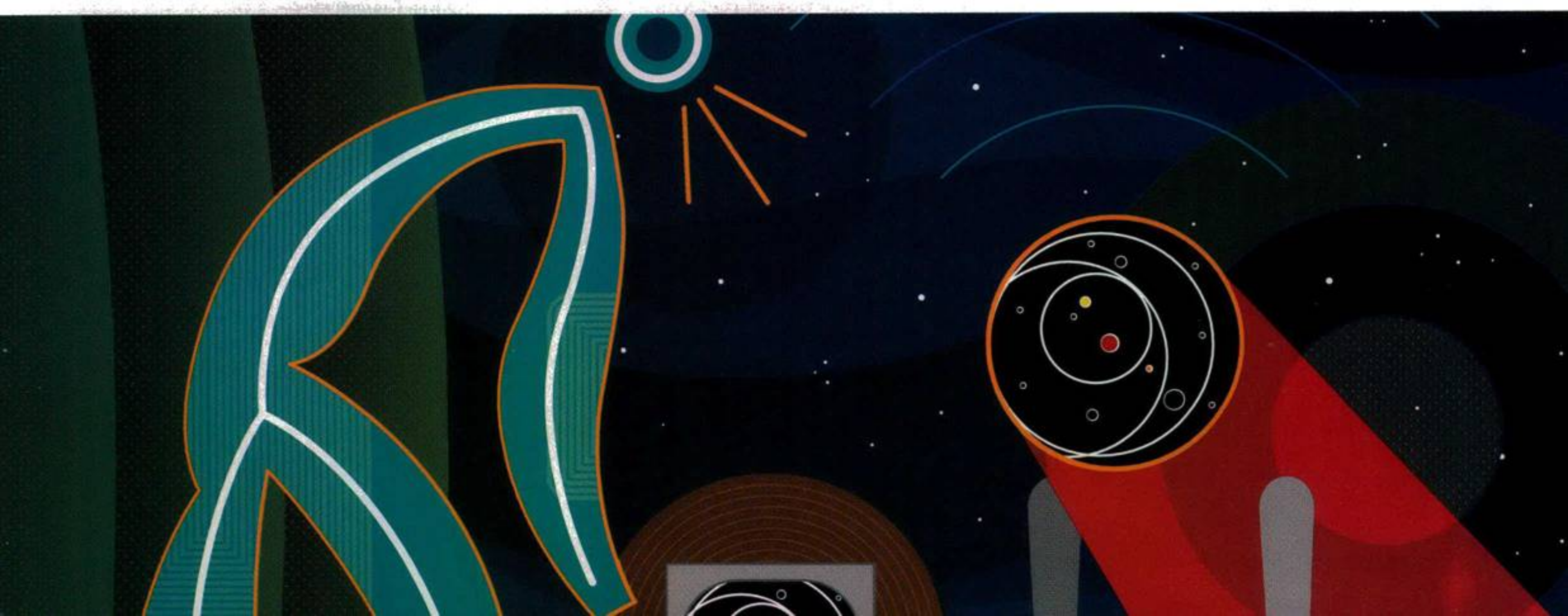

## BEHIND THE SCENES

BY BONNIE BILYEU GORDON

# The Wait for "Falling Stars"

As the eclipse waned, many of the pilgrims on *Astronomy* magazine's safari were dancing to the beat of African drums. Some were sipping champagne and congratulating each other. This was a rare event, seen live by only several thousand people. The countries that enjoyed the 2001 eclipse were small and difficult to reach — the countries of southern Africa. Many are suffering political troubles or recovering from natural disaster. And few have extensive tourist facilities.

Now in August we are home and look forward to another fine night sky event, one that will be accessible to nearly everyone who reads this magazine. This personal favorite will be the Perseid meteor showers.

I grew up in San Diego, but my backyard faced "undeveloped land." In those days in California that meant the land was agricultural and not paved or filled with oversized imitation colonials. (My own house was in a development called Princess Houses after the charming touches that Disney might have envisioned.) From a blanket in my backyard I used to lay on my back with my parents while they taught me to recognize many of the constellations. Later I would watch the night with a series of boyfriends, letting each one pretend to show me Orion for the first time. (That's what lady-like behavior required when I was a teenager.)

Frank Zullo

**A meteor surprises the night sky.**

The skies were very dark, it seems to me, and even from the edge of a big city, we could see hundreds of objects. Mostly, though, we marshaled our patience for shooting stars; they were the prizes. Later I discovered that shooting stars were meteors, tiny bits of asteroids that blazed as they fell through Earth's atmosphere. Still later I found that on special nights each year, the sky rained meteors.

I was only a little disappointed to learn about these regular meteor showers. I wanted shooting stars to be so rare that only especially lucky, careful people ever saw one. Over time I grew into a busy adult and parent, and I learned to love early August for its certain display.

Though my late trip to Africa was rare and decidedly wondrous, it could be no better than a sky filled with shooting stars. To watch this year's Perseid display, find yourself a dark soccer field or a national park, if you must, and spread a blanket. The meteors come more frequently after midnight, and by then the waning moon has set. On August 11, plan the night around an event that's lovely, consistent, and easy-to-appreciate.

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*Astronomy* (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: 800-533-6644; outside the U.S. and Canada: 262-796-8776, ext. 421, Monday through Friday, 8:30 A.M. to 5 P.M. CT, Fax: (262) 796-1615; E-mail: customerservice@kalmbach.com. Please include your name, mailing address, and telephone number with any correspondence. Copyright © 2001 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Periodicals postage paid at Waukesha, WI, and additional offices. Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription rate: single copy: $4.50; 1 year $39.95, 2 years (24 issues) $74.95, 3 years (36 issues) $106.95; Canadian & foreign: 1 year $50, 2 years $95, 3 years $137. Payable in U.S. funds drawn on U.S. Banks. (Canadian price includes GST.) Expedited Delivery Service Surcharges: Domestic 1st Class $30 per year, Canadian air $30 per year, Foreign air, $60 per year. BN 12271 3209 RT. Canada Post Publication Agreement Number 545-775. Not responsible for unsolicited materials. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612.

# LX10

MEADE® 8" LX10

## NOW WITH FREE FIELD TRIPOD FOR A LIMITED TIME!

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**Super-Multi-Coated Optical System:** The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as the more expensive Meade 8" LX200.

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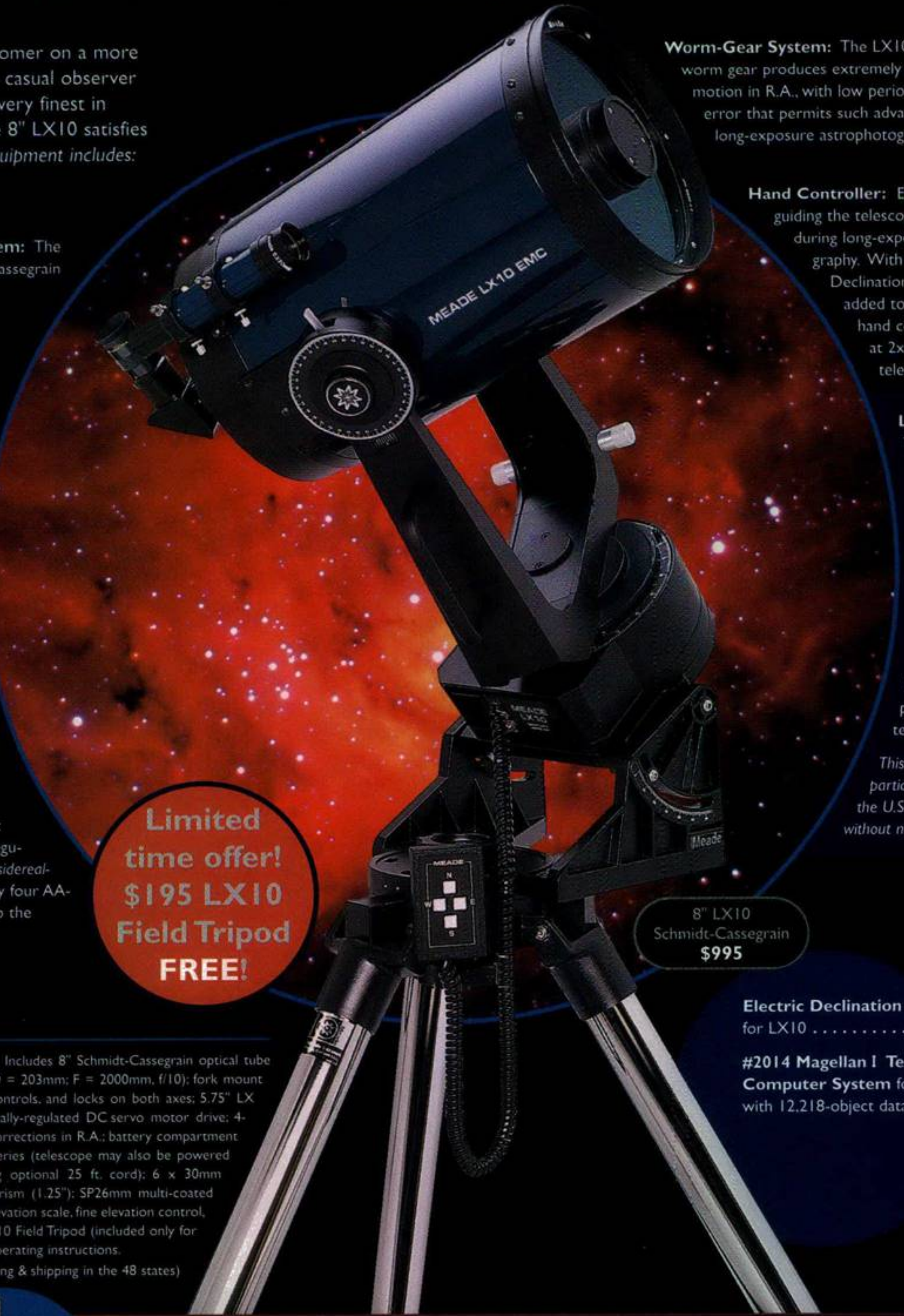

Limited time offer! $195 LX10 Field Tripod FREE!

8" LX10 Schmidt-Cassegrain **$995**

**Worm-Gear System:** The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

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**LX10 Field Tripod:** The chromed steel LX10 Field Tripod provides an extremely rigid platform for visual and photographic observations with the telescope. Regularly $195, this tripod is included **free of charge** for a limited time with your purchase of the 8" LX10 telescope.

*This free offer is valid at participating Meade dealers in the U.S.A. and may be cancelled without notice at any time.*

| | |
|---|---|
| **Electric Declination Motor System** for LX10 | **95.** |
| **#2014 Magellan I Telescope Computer System** for LX10 with 12,218-object database | **375.** |

**SPECIFICATIONS: 8" Model LX10** — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; LX10 Field Tripod (included only for a limited time, as noted above); complete operating instructions.

**$995.** (+ $65 packing & shipping in the 48 states)

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**Automatic dual-axis GO TO function at 4.5°/sec.** to any of more than 1450 database objects, including the complete Messier and Caldwell deep-space object catalogs, the major planets from Mercury to Neptune, 26 asteroids, 15 periodic comets, and more. Or GO TO *any* object of known R.A. and Dec.

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| #773 Hard Carry Case (70) | 59.95 | #774 Hard Carry Case (90) | 99.95 |
| #933 45° Erecting Prism (70) | 49.95 | #775 Hard Carry Case (125) | 149.95 |
| #64ST Photo Adapter (70) | 19.95 | #932 45° Erecting Prism (90, 125) | 49.95 |
| #497 Autostar Computer Controller (90, 125) | 149.00 | #64 Photo Adapter (90, 125) | 34.95 |
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| #881 Equatorial Table Tripod (125) | 59.95 | | |

*see also the Meade accessory ad in this issue.*

**SPECIFICATIONS: ETX-70AT Astro Telescope** — Includes achromatic refractor optical tube assembly (D = 70mm, F = 350mm, f/5) with multi-layer optical coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles, and locks on both axes; electronic control panel; 9-speed (2x sidereal through 4.5°/sec.) dual-axis motor drive system with #494 Autostar computer controller; sidereal-rate tracking; internal compartment accepting six (user-supplied) AA-size batteries; MA9mm (39X) and MA25mm (14X) multi-coated eyepieces; #882 Standard Field Tripod (included only for a limited time, as noted above); operating instructions.
**ETX-70AT — $299** (+$10 packing & shipping in the 48 states)

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ETX-90EC **MEADE** ETX-125EC

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**Fork Mounts with Dual-Axis Drive Systems:** Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

**Pushbutton Electronic Hand Controller:** Use any of four dual-axis speeds: 8x, 32x, 0.75°/sec., or 5°/sec.

**Maksutov-Cassegrain Optical Systems:** ETX diffraction-limited optics produce images so high in contrast and resolution that ETX telescopes often outperform other telescopes of larger apertures.

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**Autostar $99 for a limited time!**

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- **Automatic dual-axis GO TO function** at 5°/sec to any of more than 14,000 database objects.
- Select any of Autostar's database objects, or any object of known R.A. and Dec., press ***GO TO*** and the telescope automatically slews to the object.
- **9-Speed Dual-Axis Operation** from 2x sidereal to 5°/sec.

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**SPECIFICATIONS: ETX 90EC and ETX-125EC Astro Telescopes —** Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $495** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

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Orders & Info.: 800-621-2248; IL: 847-367-4600.

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# RESEARCH-GRADE ACCESSORIES

## Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

**Super Plössls** (SP; 4-elements; 1.25"; 52°):

| | | |
|---|---|---|
| **6.4, 9.7, 12.4, 15, 20, 26mm** | each: | **$79.95** (4.54) |
| **32mm** (52°); **40mm** (44°) | each: | **99.95** (5.26) |
| **56mm** (52°; 2") | | **199.95** (7.02) |

## Series 4000™ 2x Apochromatic Barlow Lens

**#140:** The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

**$79.95** (5.26)

## Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

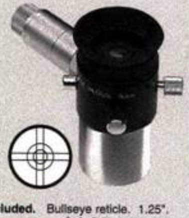
**Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

## Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

**Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

## World's Most Advanced Illuminated Reticle Eyepiece



**Series 4000 Plössl 9mm,** with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

**$149.95** (6.14)

**Series 4000 Plössl 9mm**—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

**$129.95** (5.26)

## Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

**Series 3000 Plössls** (4-elements; 1.25"; 50°)

**5, 6.7, 9.5, 16, 25mm** each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

## Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

**$129.95** (5.26)

**Series 4000 Photo-Visual Color Filters** (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

**#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue**

each **$14.95** (2.73)

| | |
|---|---|
| **Set #1**–4 filters: #12, #23A, #58, #80A | **49.95** (4.54) |
| **Set #2**–4 filters: #11, #25A, #47, #82A | **49.95** (4.54) |
| **Set #3**–4 filters: #8, #21, #38A, #56 | **49.95** (4.54) |

**Series 4000 Moon Filter (#ND96):** Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#911B
#910B
#908B
#911N
#910N
#908N

**Series 4000 Nebular Filters**—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

| | |
|---|---|
| **#908B**–Threads into 1.25" eyepieces, 26mm dia. | **79.95** (4.54) |
| **#910B**–Threads into 2" eyepieces, 44mm dia. | **119.95** (5.26) |
| **#911B**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **99.95** (5.26) |
| **#908N**–Threads into 1.25" eyepieces, 26mm dia. | **89.95** (4.54) |
| **#910N**–Threads into 2" eyepieces, 44mm dia. | **129.95** (5.26) |
| **#911N**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **119.95** (5.26) |

#911X
#910X
#908X

**Series 4000 Oxygen-III Filters** Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

| | |
|---|---|
| **#908X**–Threads into 1.25" eyepieces, 26mm dia. | **99.95** (4.54) |
| **#910X**–Threads into 2" eyepieces, 44mm dia. | **159.95** (5.26) |
| **#911X**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **149.95** (5.26) |

## 2x Telenegative Barlow (1.25")

**#122:** Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

**$47.95** (4.54)

## #905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

## 2x Short-Focus Barlow (1.25")

**#126:** Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

**$47.95** (4.54)

## 2x-3x Variable Barlow (1.25")

**#127:** Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

**$59.95** (4.54)

## 2" Diagonal Mirror

**#929:** Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron *SCT's*. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

**#929** or **#930**, each: **$99.95** (6.85)

## 45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

**$42.95** (3.86)

## Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

**#1206 Electric Focuser:** Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

**#1205 Electric Focuser:** For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

**$169.95** (7.88)

## #777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

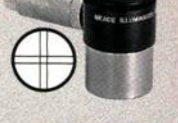
**$79.95** (6.85)

## Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

## MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries Included.**

**$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

## Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (3.86)

## Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

**$39.95** (3.86)

## Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

**$39.95** (3.86)

## T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

**$26.95** (3.86)

## CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with *any* brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

*"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope."* — Jack Newton

**#644 Flip-Mirror System:** Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

**#647 Flip-Mirror System:** Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

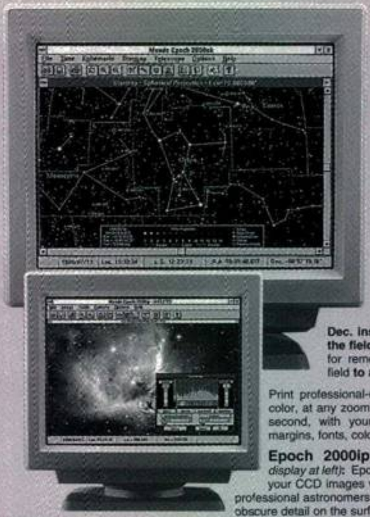
**#157 1.25" Adapter:** Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

NEW!
MEADE
MEADE

#644

#647
MEADE
FLIP-MIRROR SYSTEM

## Epoch 2000® Sky Software



### The most powerful astronomical software ever made available can now be yours for only $149!

**Epoch 2000sk** *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

**Epoch 2000ip Image Processing Software** *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

**EPOCH 2000sk Sky Software:** 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . . . . . **$149**

**EPOCH 2000sk-CD Sky Software:** 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM . . . . . . . . **179**

**LX200 Interface Cable:** for Meade LX200 operation by Epoch 2000sk . . . . . . . . **25**

**EPOCH 2000ip Image Processing Software:** Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . . . . . **$199**

## Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

f/3.3 CCD FOCAL REDUCER

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

## Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

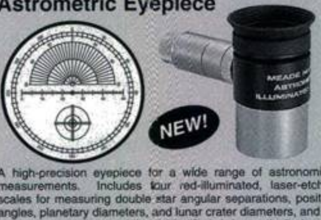
## #825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

## #64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

## MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

## Series 4000™ 8mm – 24mm Zoom Eyepiece

NEW!

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

## ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, plus optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes two steel latches with key.

**#774** Case for ETX-90 models: **99.95** (8.58)

**#775** for ETX-125EC: **149.95** (13.38)

## #932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90 or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **$49.95** (3.86)

## Advanced Field Tripod for ETX-125

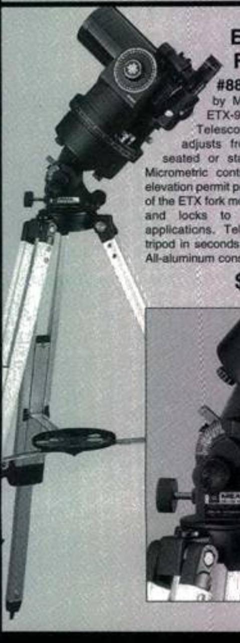
**#887:** Yields *rock-solid* stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport. **$349.95** (14.00)

## Tripod Adapter for ETX-125

Included with the #887 Tripod *(above),* the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications.

**#889 Adapter:** **$69.95** (7.70)

## ETX® Deluxe Field Tripod



**#883:** Custom-designed by Meade specifically for ETX-90 and ETX-125 Astro Telescopes. Tripod height adjusts from 34" to 54", for seated or standing observations. Micrometric controls in azimuth and elevation permit precise polar alignment of the ETX fork mount. Tripod head tilts and locks to 90° for terrestrial applications. Telescope attaches to tripod in seconds with 2 thumbscrews. All-aluminum construction. **$199.95** (10.00)

## ETX® Carry Bag

Soft-padded Cordura-type carry bag with shoulder strap; permits storage of any 90mm ETX model, plus table tripod legs, eyepieces, other accessories. **$36.95** (5.26)

## Electric Focusers for ETX®

NEW!

ELECTRONIC CONTROLLER
MEADE

Meade-engineered for smooth, rapid focusing with any ETX model. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus ETX/EC models through the telescope's hand controller.

**#1244** Electric Focuser for all ETX-90 models: **$119.95** (6.85)

**#1247** Electric Focuser for ETX-125 models: **$119.95** (6.85)

# HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

**ASTRONOMICS, Norman, OK.**
**Orders: 800-422-7876; Info.: 405-364-0858.**

**FOCUS CAMERA, Brooklyn, NY.**
**Orders: 800-221-0828; Info.: 718-436-6262.**

**LUMICON, Livermore, CA.**
**Orders: 800-767-9576; Info.: 925-447-9570.**

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**Orders & Information: 800-483-6287.**

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**Orders: 800-569-4323; Info.: 570-842-1500.**

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# Space Station Defense

In the last several issues I came across remarks critical of the International Space Station (ISS). You are certainly correct that more can be done at less cost if humans stay on Earth while machines do all the work in space, but so what? To paraphrase Daniel H. Burnham, Chicago's visionary city planner of the early 1900s, "Make no small plans, for they have no magic to stir men's souls."

If space is reserved for machines, we humans will rapidly lose interest — then just watch what happens to NASA's funding. The frame of mind that has dictated a smaller, cheaper series of space missions has led to a bunch of failed or dissatisfying missions. There is only so much the space shuttle can do. Likewise, industry will not go into space until it's profitable.

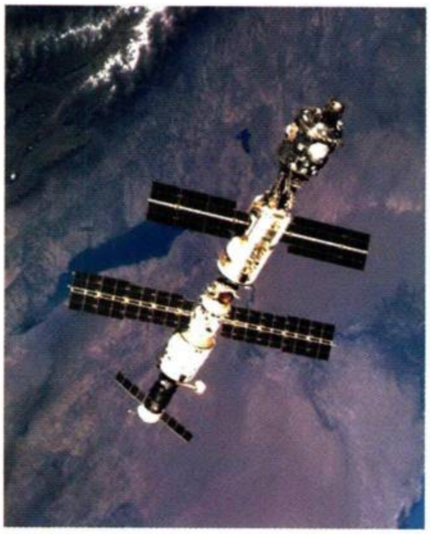
Eventually the ISS or a similar structure will be a city, complete with tourists and all that goes with it. Calling the ISS uninspiring and impractical completely misses the point, for it is indeed inspiring to so many of us. — *Russell Marra, Valparaiso, Indiana*

### Homemade Solar Filters

Because of our high latitude and proximity to the North Pole, nighttime observing in the United Kingdom becomes difficult from about mid-May until early August. I have often thought about solar viewing as a means of maintaining my interest during this time, and found Phil Harrington's article "Here Comes the Sun" (April 2001) very useful indeed.

I ended up making my own filters. For £12 (around $17), I bought a sheet of Baader filter material and made filters for several pieces of equipment: a 76mm catadioptric telescope, a 60mm refractor, two finderscopes, and a pair of 15x70 binoculars.

Although I haven't had a really clear day since I made the filters, I can identify large sunspot groups using my binoculars. The most amazing sight was when I used the refractor at 240x to get a close-up of a large sunspot group, and observed both umbral and penumbral regions simultaneously.



**Conflicting opinions surround the International Space Station.** NASA

Since then, I've taken my equipment to work. While I don't think any non-astronomers will be rushing out to buy telescopes, it's nice to see some interest. I will probably hold lunchtime sessions every other week. And I don't think my filters will be gathering dust during the winter, either. — *Philip Pugh, Chippenham, Wiltshire, England*

### Filter Availability

In your solar filters review, you mention that the JMB filter is also available from Orion. What you really needed to say was to check with your local retailer to find out whether or not it carries the JMB line. We at Shutan Camera & Video have been carrying many sizes of JMB filters for years. Customers can count on JMB filters and their consistent, high quality.

Your review also failed to mention product warranty. You can't go wrong with a lifetime warranty — which is exactly what JMB offers. — *Bob Shutan, Vernon Hills, Illinois*

### Laser Eye Damage

I believe that the potential for laser pointers to cause eye damage has been exaggerated ("Laser Use Rules," April 2001). In my ten years of ophthalmology, I have never seen or heard of a case where laser pointer exposure resulted in damage to an eye.

Additionally, a Mayo Clinic study in the *Archives of Ophthalmology* (2000; 118:1686–1691) concluded that the risk to the human eye from transient exposure to laser beams from commercially-available laser pointers with power outputs of 1, 2, and 5 milliwatts is negligible.

The Mayo study described a test done on three patients who eventually had an eye removed because of a malignant tumor. Two weeks prior to undergoing enucleation, each had a laser pointer aimed at his or her eye for up to 15 minutes. That gave doctors time before the surgery to ask whether or not the patients had any complaints, such as pain or loss of vision. None were reported — except for experiencing a transient after-image.

Afterwards, extensive examination and dissection of the removed eyeballs failed to find any injury to the retina. No discernable functional or microscopic changes were documented. — *David Litoff, Boulder, Colorado*

### Universal Gender

*Astronomy* has disappointed me with its use of sexist language in "Going Deep For Galaxies," (May 2001). Your first sentence, "Like intrepid explorers, astronomers are probing the farthest reaches of the universe in search of her most guarded treasure ..." Since when is the universe female? We're in the 21st Century now — please write like it. — *Jill Volpat, Indianapolis, Indiana*

### Day Sight

The editor's response to "Day Trippers" (May 2001, page 14) indicates that it is probably impossible to see the

*(continued on page 16)*

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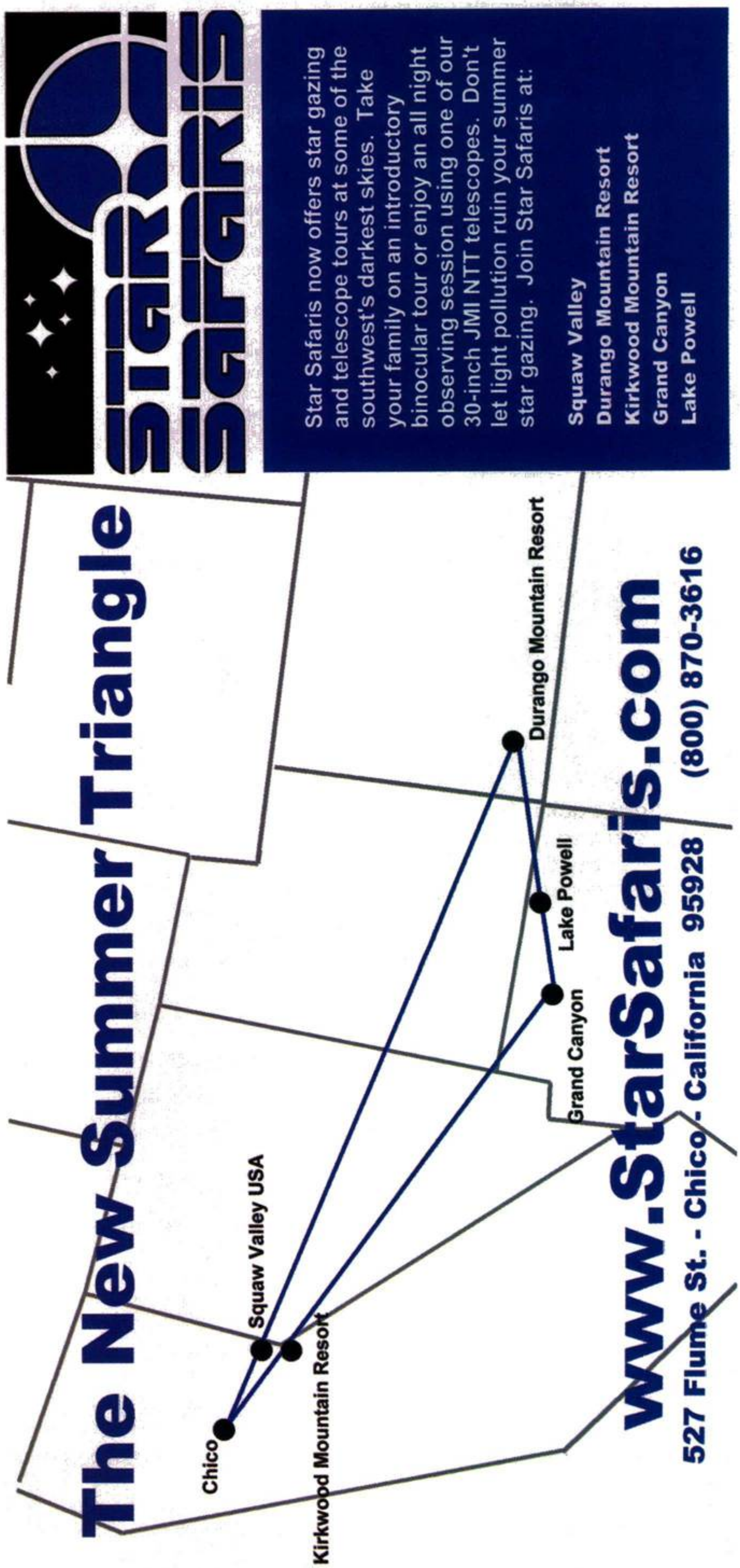

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See our website for full details on this amazing telescope.

## New lower prices on big SBIG CCD cameras!

SBIG has just brought out four new versions of the **ST-8E** 1534 x 1020 pixel enhanced blue sensitivity *self-guiding* two-chip imager (shown above). They've reduced prices on the ST-8E and ST-7E as well!

You can choose from three levels of chip cosmetics with the ST-8E, depending on your budget and imaging needs. Each chip level is available either with or without antiblooming, as you prefer. For spectroscopy, photometry, and critical imaging applications, Class 1 chips have no column or point defects.

The Class 2 versions have no column defects and a very limited number of point and cluster defects. This spec is actually an upgrade of the former ST-8E, at a price that's $1355 lower than the previous models! The Class 2 versions are designed for most scientific applications and excellent imaging.

*The entry level* Class 3 chip allows for some column, point, and cluster defects, but these can be eliminated by software for very good astronomical imaging at a price that's $1500 below competitive cameras with a similar size chip (although at the expense of somewhat restricted scientific applications).

We stock almost all available models of the Apogee LISÄÄ, Meade Pictor, and SBIG CCD cameras, self-guiding cameras, and autoguiders. We also carry a wide range of CCD accessories, as well – flip mirror systems, off-axis guiders, color filter wheels, image processing software, and more. Our large inventory means that the chances are good you won't have to wait to get the camera or accessory of your choice. Here are the SBIG cameras we normally keep in stock and their prices.

| | |
|---|---|
| **SBIG ST-5C** track/accumulate camera | 895<sup></sup>$^{00}$ |
| **SBIG ST-237** track/accumulate camera | 1195$^{00}$ |
| **SBIG ST-7E** self-guiding camera, Class 1 | 2650$^{00}$ |
| **SBIG ST-8E** self-guiding camera, Class 1 | 7350$^{00}$ |
| **SBIG ST-8E** self-guiding camera, Class 2 | 5995$^{00}$ |
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| **SBIG STVD** digital video w/LCD screen | 2250$^{00}$ |

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In addition to telescopes, we stock TeleVue eyepieces; Barlows; camera adapters; mounts; Starbeam and Qwik-Point finders; and all other accessories in depth. If it's a product that comes from TeleVue, the chances are good we have it in stock for immediate shipment.

TeleVue eyepieces, all models in stock

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Takahashi FSQ-106N OTA (4" f/5), **$3475**, on an EM-2 mount, **$2229**. Also shown is the FS-102 4" f/8 OTA, **$2349** w/o finderscope.

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Takahashi FCL-90 ***Sky 90*** OTA (3.5" f/5.6), shown with dew shield retracted, **$2279**

A very hot Takahashi is the unique **FCL-90 *Sky 90*** 90mm f/5.6 refractor. With its self-storing dew shield retracted, as shown above, this remarkable telescope is less than 14" long! It makes a great traveller scope that you can stow away anywhere – *and it's available!*

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CELESTRON

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jovian moons in daylight. However, I have seen them on more than one occasion with our 22-inch Maksutov telescope that we use here at the Stamford Observatory in Connecticut.

I have also seen Saturn and its rings during the day. (Although I admit that the rings are quite faint — depending upon how wide open they are).

Keep in mind that looking through our 22-inch telescope in daylight is equivalent to stargazing at night with a 12-inch scope because of the narrowing of your pupils.

Also, daytime viewing of Venus is rather easy, while Mars and Mercury are more difficult to spot, but I have seen them all. These feats should be possible with many telescopes available to amateurs. — *Charles E. Scovil, Director, Stamford Observatory, Stamford, Connecticut*

### Pole Reversal

The orientation of Bob Vandusen's photo, "The Central Face of the Moon" (June 2001, page 107) puzzles me. I know it's common to show astronomy images mirrored, but why print them upside-down as well? — *Bob Choinard, Sterling Heights, Michigan*

*We prefer to orient a photo the same way our readers would see the image during an observing session. If the photo is a wide-field shot visible to the naked eye or with binoculars, we print that image with north at the top.*

*Most telescopes show relatively small areas of an object. Typically, telescopes show an inverted image with or without also reversing the image left-right (a mirror image).*

*Our aim is to print images consistent with those seen by the largest number of observers. That way, we match what people will actually see and instantly recognize.* — Astronomy editors

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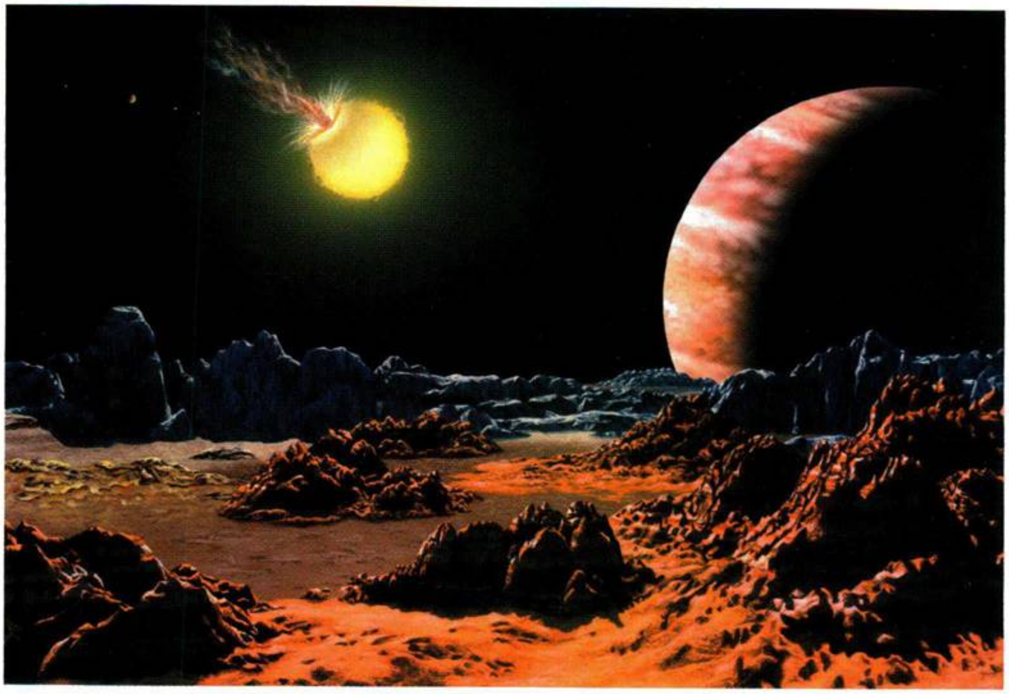
EXTRASOLAR PLANETS

# Spying a Planet-Eating Star

▶ The 65 or so extrasolar planets found to date tell a tale of chaotic and violent evolution. In some systems, planets migrate inward toward their host stars, occasionally parking in tight, star-hugging orbits. In other systems, two or more massive planets gravitationally slingshot one another into highly elongated orbits. Every now and then, however, these processes will direct a planet right into its host star. When this happens, the ravenous star will swallow the entire planet whole.

In a paper published in the May 10, 2001, issue of *Nature*, a team of European astronomers led by Garik Israelian of the Institute for Astrophysics of the Canary Islands and Michel Mayor of the Geneva Observatory report evidence that at least one solar-type star has swallowed one or more planets. The star, HD 82943 in Hydra, is known to have at least two Jupiter-class planets orbiting in elongated ovals, strongly suggesting that this system underwent violent evolution.

Using the Kueyen Telescope, one of the four 8.2-meter telescopes that comprise the European Southern Observatory's Very Large Telescope in Chile, Israelian's team found the spectral fingerprint of the fragile isotope lithium-6 in HD 82943's upper atmosphere. The team ruled out other possible explanations for the lithium-6 signature, such as star spots and flares.



Lynette Cook

**A planet falls into the sunlike star HD 82943. This view is from a hypothetical moon of one of the system's two known giant planets.**

Under normal circumstances, lithium-6 shouldn't be there. In the core of a sunlike star, protons will collide with lithium-6 atoms and destroy them within a few million years. That's why lithium-6 almost never appears in solar-type stars like HD 82943, which is about 6 billion years old. Planets, on the other hand, never become hot enough to consume their initial supply of lithium-6.

The strength of the spectral lines implies that the star contains $3.2 \times 10^{44}$ atoms of lithium-6 in its upper layers. "To account for this much lithium-6, we estimate that the star had to swallow the equivalent of a two-Jupiter-mass giant planet during its lifetime, or a terrestrial planet (or planets) with a total of three times the mass of Earth," says Israelian.

The star must have consumed the planet or planets at least 20 million years after being born. In young stars, a thick convection zone cycles material from the upper layers into the core, where proton collisions would destroy lithium-6. But as a star settles down some 20 million years after its birth, the convection zone shrinks and material in the upper layers remains there. Theorists believe planets form 10 to 20 million years after their host star does, so the timing of the ingestion makes sense.

"The only explanation for the high lithium-6 content in this star is the planet ingestion scenario," says Israelian.

Other astronomers remain unconvinced. "I think planet ingestion is not only plausible but highly likely to have occurred in some stars. But the question is, how can we *prove* that it has happened?" says planetary formation theorist Alan Boss of the Carnegie Institution of Washington, D.C. "I think the lithium story is too uncertain to make any firm claims regarding planetary ingestion. It remains a logical possibility, but so far as I can tell, no one has yet found conclusive evidence for the bones left over from a planetary meal."

Israelian's team plans further observations to confirm or reject the ingestion scenario. —

ROBERT NAEYE, ASTRONOMICAL SOCIETY OF THE PACIFIC

*BLACK HOLES*

# Black Hole Goes for a Spin

▶ If the research of a lone NASA astronomer holds up, dancing black holes may dot the universe. Okay, so they probably aren't doing the mambo or tango. But new x-ray observations, revealed at this year's American Physical Society Spring Meeting in Washington, D.C., finally confirm the long-held notion that some black holes are capable of the most rudimentary form of dance — spinning.

"Almost every kind of object in space spins," says Tod Strohmayer of NASA's Goddard Space Flight Center in Greenbelt, Maryland. "With black holes, it's much harder to directly see that they are spinning, because they don't have a solid surface that you can watch spin around."

Astronomers have long suspected that some black holes must spin, because they conserve the angular momentum inherited from material they've consumed. But Strohmayer's research marks the first solid observational evidence that at least one black hole really does spin. Using the Rossi X-ray Timing Explorer (RXTE) satellite, he targeted a microquasar called GRO J1655–40 — a jet-producing binary system that contains a black hole and normal star located 10,000 light-years from Earth. (For more on microquasars, see "Quasars Next Door," July 2001.)

Since 1995, RXTE has detected quasi-periodic oscillations (QPOs) in many x-ray binary systems. Astronomers think that these outbursts arise from hot, accreting material orbiting a neutron star or black hole near the inner edge of stability. The higher the QPO frequency, the faster (and closer) the material is believed to orbit.

Strohmayer recently detected a QPO in GRO J1655–40 that has a frequency of 450 hertz, or 450 cycles per second. With a dash of Einstein's general theory of relativity and a sprinkle of deductive logic, he's shown that the black hole in this system must be spinning.

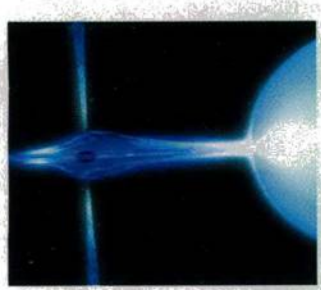
"The accretion disk around a black hole has a limiting radius, which is called the innermost stable orbit or the last stable orbit," explains Strohmayer. "Material inside the innermost stable orbit will simply fall straight into the black hole." And depending upon whether the black hole is spinning or not, the innermost stable orbit will lie closer or farther away from the black hole, respectively.

According to Strohmayer, the high-frequency QPO in GRO J1655–40 suggests that material is orbiting well inside the innermost stable orbit for a non-rotating black hole.

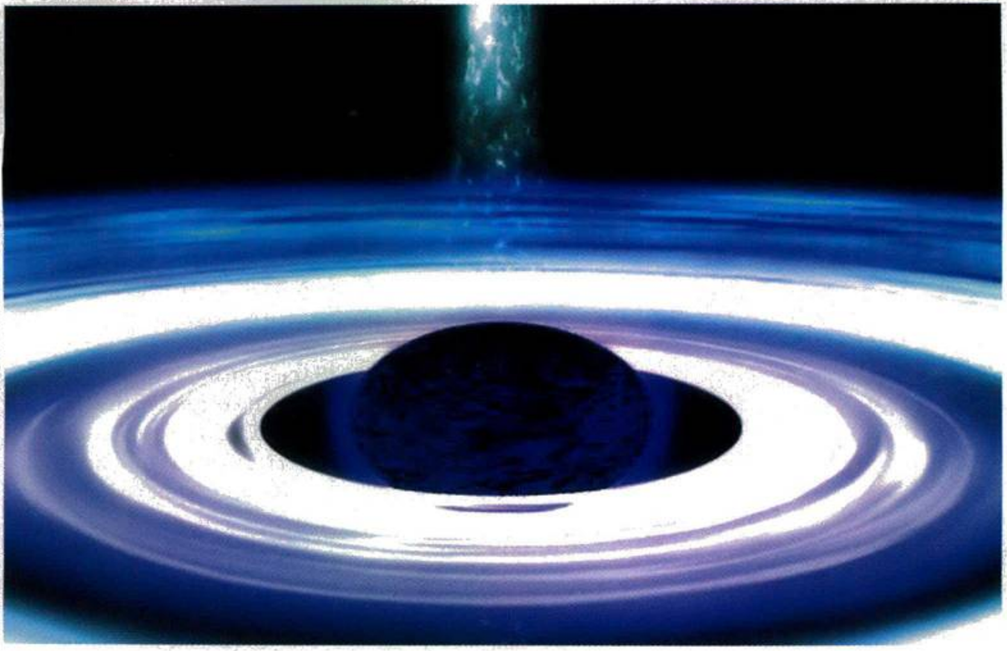
"You don't have a stable orbit that close to the black hole," says Strohmayer, "unless it's spinning."

Spinning black holes are able to sustain closer stable orbits and generate higher frequency QPOs than their sedentary counterparts. That's because a spinning black hole warps the fabric of space surrounding it, dragging space along (and drawing it in) as it rotates.

— **William Schomaker**



**A computer animation shows a black hole sucking material from its blue giant companion (left), forming an accretion disk and ejecting two high-speed jets. A closer view (below) reveals the gap between the black hole and x-ray-emitting disk, representing the innermost stable orbit possible.**



Both animations: NASA/Honeywell Max-Q Digital Group/Dana Berry

*PLANETARY SCIENCE*

# Getting a Rise out of Mars

▶ Like studying the rings in the trunk of a tree, examining the present state of a planet's surface can yield valuable insight into how the planet formed and evolved. Now a team of planetary scientists has found the martian equivalent of a giant sequoia, a feature that may provide researchers with long-sought answers about the Red Planet's early climate, shape, and its distribution of water.

The team, led by Roger Phillips of Washington University in St. Louis, Missouri, recently looked at the enormous influence of the great Tharsis rise, which dominates the western hemisphere of Mars. This broad expanse of land rises 6 miles (10 kilometers) above the average surface of Mars — higher than Mount Everest rises above sea level on Earth — and spans more than 10 million square miles (30 million square kilometers) — nearly the size of Asia. Using data from the Mars Orbiter Laser Altimeter instrument aboard NASA's Mars Global Surveyor satellite, Phillips and his colleagues compared topographical and gravitational features of Mars with theoretical predictions.

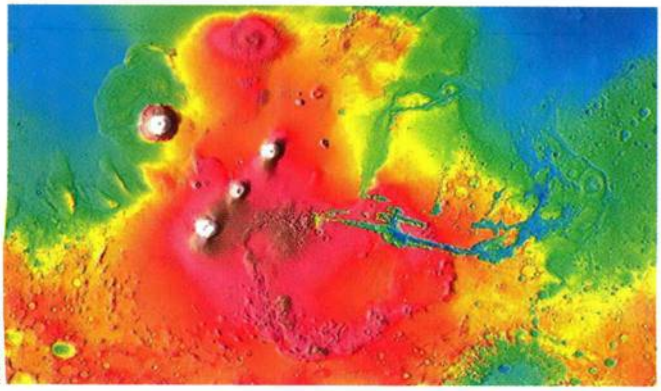
The research, which appears in the March 30, 2001, issue of *Science*, reveals that the massive influx of magma that formed the Tharsis rise changed the shape of the planet's rigid outer layer, or lithosphere. This buildup of volcanic material also caused a trough to form around the Tharsis rise and produced a bulge at Arabia Terra on the opposite side of the planet.

"Imagine that Mars is a beach ball and that the Tharsis load is your fist," explains Phillips. "As your fist punches into the beach ball, there's a bulge created on the opposite side of the ball and a depression or trough surrounds your fist."

Phillips thinks that the trough may be responsible for the location and orientation of valley networks and outflow channels, which seem to flow toward it.

Planetary scientists believe that both Earth and Mars began with similar atmospheres, but evolved differently. The formation of the martian valley networks dates to the late Noachian period — Mars's oldest time period that extends back to 4.6 billion years ago and ended between 3.8 and 3.5 billion years ago. Because the mass load of the Tharsis rise caused this topography, most of the Tharsis rise must have been in place by the end of the Noachian period. This information will allow scientists to compare the state of Earth's evolution during the same time period.

In addition, the team's research bolsters the possibility that liquid water once flowed on Mars. According to Phillips, the release of carbon dioxide and water into the atmosphere by volcanism during the formation of the Tharsis rise may have been "sufficient to warm the atmosphere to the point at which liquid water was stable at the surface." That water could have also contributed to the erosion of other topographic features on the planet's surface. — Lindsay Renick Mayer



**The Tharsis region (in orange, pink, and red) rises 6 miles above the rest of the martian surface.**

MOLA Science Team

LOCAL GROUP SURVEY

AURA/NOAO/NSF

**IF ONLY EDWIN HUBBLE HAD LIVED to see this view of the Andromeda Galaxy (M31). Hubble changed our view of the universe in the 1920s when he used the 100-inch Hooker Telescope on Mt. Wilson to resolve Cepheid variable stars in M31. By analyzing their light output, he proved that galaxies existed beyond our own. Now, at the dawn of the 21st century, astronomers are surveying the galaxies in our Local Group with unprecedented detail. This image shows the northwest portion of M31's disk — about 20 percent of the planned survey region in this galaxy. It was taken with the Mosaic camera attached to the 4-meter Mayall Telescope at Kitt Peak National Observatory in Arizona. The survey's ultimate goal is to record the detailed light output of roughly 100 million stars in the Local Group of galaxies, including M31, M33, NGC 6822, IC 1613, WLM, Pegasus, and Phoenix.**

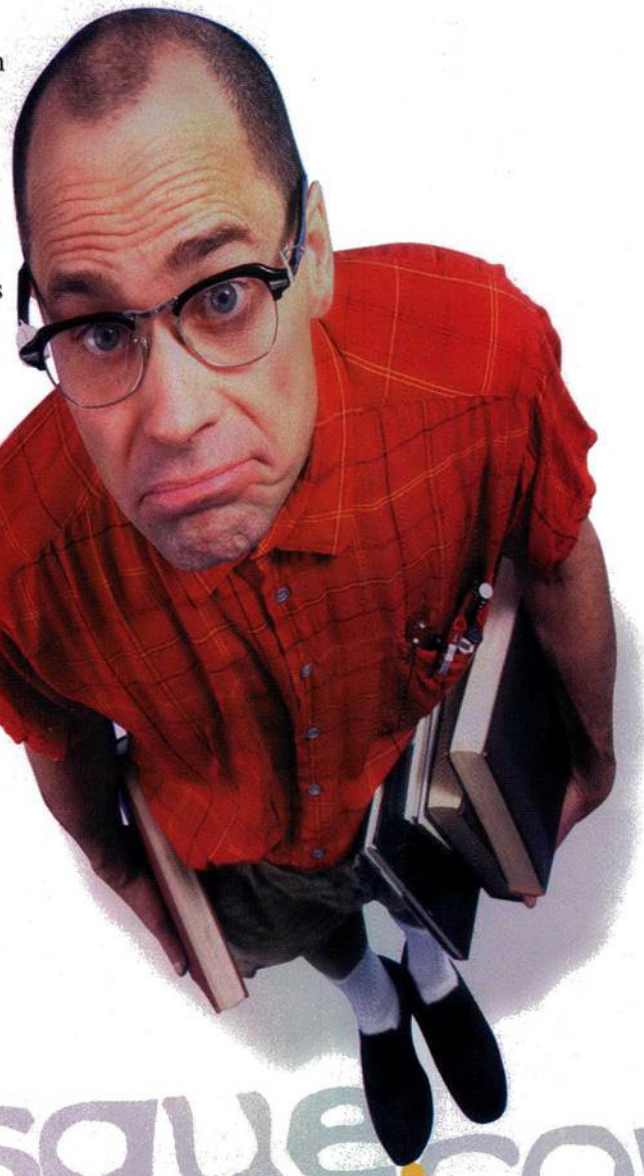
*LOCAL GALAXY GROUP*

# Nearby Galaxy Rich in Pulsars

▶ Astronomers often downplay our place in the cosmos. Our sun, they say, is just an average star, the Milky Way an average galaxy. And that's true, to a point — stars and galaxies far bigger than our own do exist. Yet it pays to remember that the vast majority of other systems fall well short of our own.

There's no need to point that out to the small galaxies held in thrall by the mighty Milky Way. The latest case in point: A close encounter with the Milky Way a few million years ago apparently triggered a burst of star formation in the Small Magellanic Cloud (SMC), an irregular galaxy located 200,000 light-years away in the constellation Tucana.

The evidence has been building over the past few years, as astronomers realized that the SMC harbors many hot young stars and a large concentration of x-ray pulsars. Now a team of researchers led by Robin Corbet of



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Universities Space Research Association has discovered two more x-ray pulsars, raising the total to 25.

"The discovery of so many x-ray pulsars has surprised most astronomers," says team member Silas Laycock of the University of Southampton in England, who presented the findings in April at the Gamma Ray 2001 meeting in Baltimore, Maryland.

"A few years ago we knew of only one pulsar in the Small Magellanic Cloud," he adds. "Now we are at 25 and still climbing." With a mass only 1/50 that of the Milky Way, the SMC has a density of x-ray pulsars at least ten times higher than our galaxy.

An x-ray pulsar is a rapidly spinning neutron star — the collapsed remnant of a massive star that exploded as a supernova — in a binary system with a normal companion. As the pulsar's strong gravity siphons material from the companion star, its powerful magnetic field channels the incoming gas onto the pulsar's poles. The gas reaches speeds up to 20 percent that of light, growing incredibly hot and emitting copious x rays.

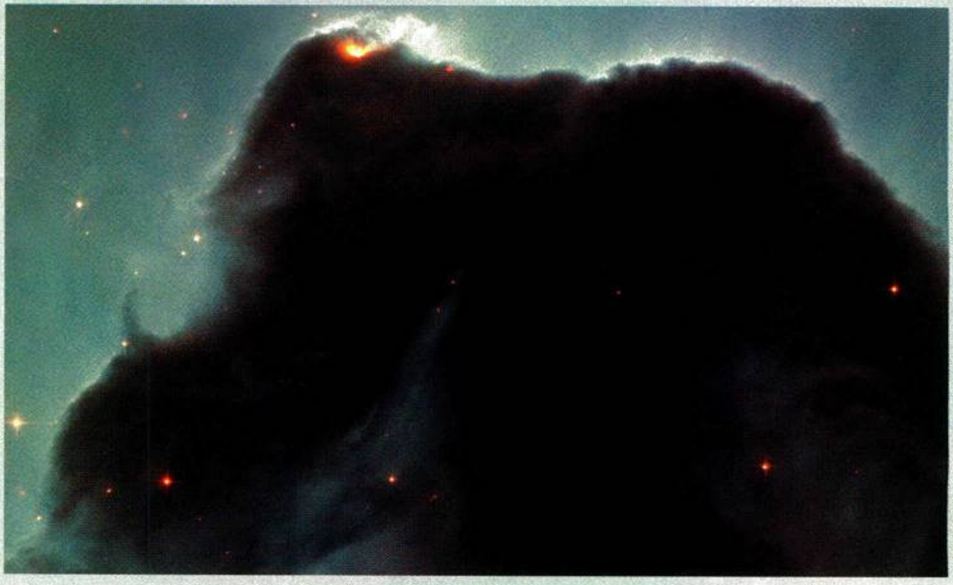
X-ray pulsars have very short lives, says Corbet, as do the massive stars that become supernovae. So the high-density of x-ray pulsars means the SMC must have undergone a burst of star formation quite recently — within the last 5 million years. That coincides with a close approach to the Milky Way as the SMC orbited our galaxy. Corbet suggests that the Milky Way created large tidal forces in the SMC, inducing the high birth rate.

— Richard Talcott

**The Small Magellanic Cloud (at bottom) underwent a burst of star formation 5 million years ago.**

Mike Mayerchak

**HUBBLE SPACE TELESCOPE**



NASA, NOAO, ESA, and the Hubble Heritage Team (STScI/AURA)

**ORION'S HORSEHEAD NEBULA RANKS NEAR THE TOP of any astrophotographer's list of favorite subjects. Internet voters followed suit when they picked the Horsehead as the target of choice for the Hubble Space Telescope. The Hubble Heritage Project released the photo in April to celebrate the orbiting observatory's 11th anniversary. The Horsehead is a cold, dark cloud of interstellar gas and dust silhouetted against a bright nebula, IC 434. The bright area toward the image's top left is a young star still embedded in its nursery of gas and dust. Unfortunately, ultraviolet radiation from this young star is slowly eroding the Horsehead, as is another hot star off the top of this Hubble view. The nebula lies just south of the bright star Zeta Orionis, the left-hand star in Orion's Belt. Although the Horsehead photographs brilliantly, backyard observers often use it as a test of their observing skills and the night's conditions — it's one of the tougher objects to see in an amateur telescope.**

*PLANET FORMATION*

# Survival of the Fittest?

▶ Imagine building a skyscraper in the middle of a tornado: That's exactly how Southwest Research Institute astronomer Henry Throop describes the challenges facing "wannabe" planets at the heart of the Orion Nebula — the nearest star-forming region to Earth at a distance of 1,500 light-years.

Following the latest Hubble Space Telescope observations of dust-laden, doughnut-shaped protoplanetary disks around newly formed stars near the region's hottest star, Theta$^1$ Orionis C, Throop and his colleagues recently uncovered evidence that the initial stages of planet formation are already underway. But they also found that time may be short for these budding planetary systems, as they battle blistering ultraviolet (UV) winds generated by the neighboring hot star.

The team's observations of dust formation in protoplanetary disks may ultimately answer the question of how common

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or rare extrasolar planets really are. Astronomers believe that the Orion Nebula's stellar furnace is responsible for spawning 10,000 or more low-mass, sunlike stars — each with the capacity to form planets from leftover material — in the last several million years. Whether planetary systems can survive to full maturity without being ripped apart, however, depends upon their surroundings. If bright, hot stars like Theta$^1$ Orionis C lie nearby, the prognosis may not be so good.

"It's a mixed picture," says team member John Bally of the University of Colorado. "We are seeing the destruction by UV light of most dust disks circling the smaller stars. At the same time, a few disks in the quieter, outer parts of the nebula show evidence for significant grain growth."

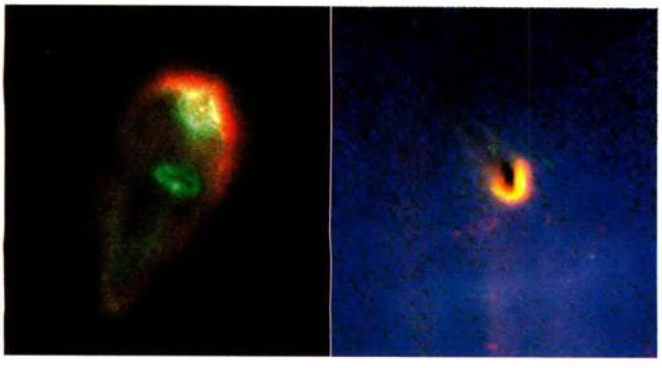
Bally and Throop used Hubble to investigate the behavior of smoke-sized dust particles in several protoplanetary systems. The way that optical and infrared light reflects off dust depends on the size of the dust particles, allowing the team to determine that the dust grains in these systems are coalescing to form larger particles, ranging in size from snowflakes to pebbles. The researchers believe that if the particles can survive the flood of battering UV radiation to reach a diameter of at least one meter or so, planets will eventually form out of the disks.

To ultimately answer the question of how common planets are in the Milky Way will require understanding the pace at which the planet formation process can take place. If planets manage to take hold rather quickly, say in less than 100,000 years, chances are good that they are quite common across the galaxy. On the other hand, the forecast for a planet-rich galaxy is less optimistic if planet formation is a slow, lingering process.

"We're seeing that planet formation is a hazardous process," says Bally.

The somewhat bleak picture painted by the new observations of disrupted disks appears consistent with current extrasolar planet searches. Although these searches have netted as many as 65 new planets, results indicate that only about five percent of nearby, solar-type stars have Jupiter-sized planets in orbit around them. Still, getting the final answer on how common planetary systems are will take some time. — W. S. ■

**Dusty disks surrounding Orion Nebula stars apparently have a difficult time making planets.**



NASA/STScI

## Pioneer 10 Phones Home

Although 29 years old and a little worse for the wear, the Pioneer 10 spacecraft continues to operate. In a test of communications technology for future interstellar missions, scientists established contact with the spacecraft on April 28, 2001, for the first time in eight months. "Pioneer 10 lives on," declared Project Manager Larry Lasher of NASA's Ames Research Center in Moffett Field, California. Launched in March 1972 and the first spacecraft to visit Jupiter, Pioneer 10 now lies 7.3 billion miles from Earth. Traveling at 27,830 miles per hour, it will pass the nearest star in 2 million years.

NASA/JPL

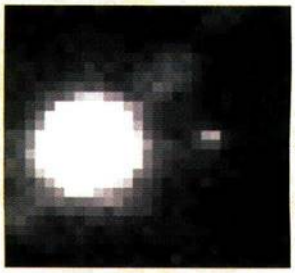
**Pioneer 10 at Jupiter in 1973.**

## Galileo Finds a Variable Star

While the Galileo spacecraft continues to make discoveries at Jupiter, no one expected it to contribute to stellar research. But that's just what it did when its star tracker apparently went on the fritz last summer, failing to recognize the bright star Delta Velorum. "I spent about a week working on it," says Paul Fieseler, an engineer for the Galileo project, "and concluded that the star tracker wasn't broken, but perhaps the star was." He sent an e-mail to the American Association of Variable Star Observers and was rewarded when amateur astronomer Sebastian Otero of Argentina reported that he had seen Delta dim four times since 1997. Astronomers have concluded that Delta is an eclipsing binary star that dims slightly for eight hours every 45 days.

## Asteroid Companions Grow to Five

Technology continues to drive the rate of discoveries in the solar system. New techniques have recently added dozens of moons to the rosters of the gas-giant planets. Now, observations with the Hubble Space Telescope have raised the number of known asteroid companions to five. In March 2001, Alex Storrs of Towson University in Maryland imaged a tiny companion to the main-belt asteroid 107 Camilla. Except for Dactyl, the companion to 243 Ida discovered when Galileo flew by, all asteroids with companions are primitive types, likely pristine samples of the material that accumulated to form the terrestrial planets.



A. Storrs (Towson University) and NASA

**Camilla's partner (right) glows faintly in this Hubble image.**

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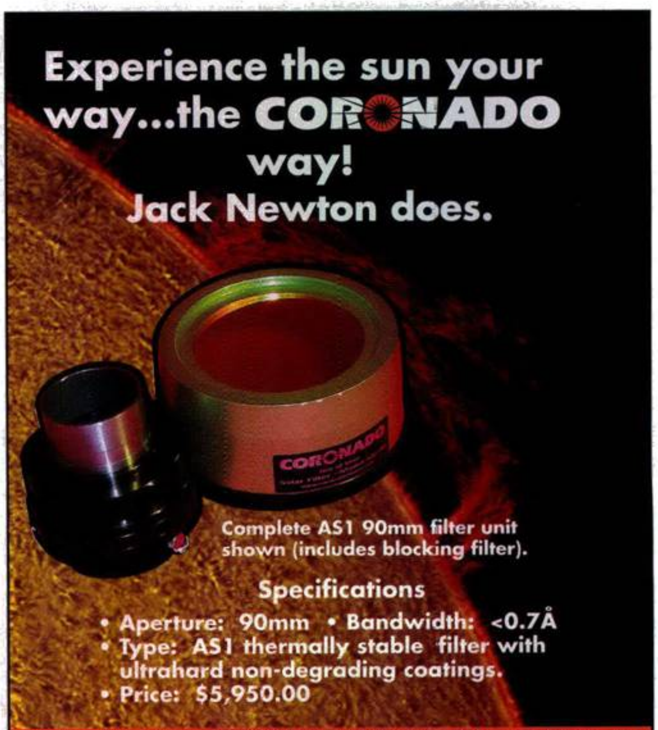

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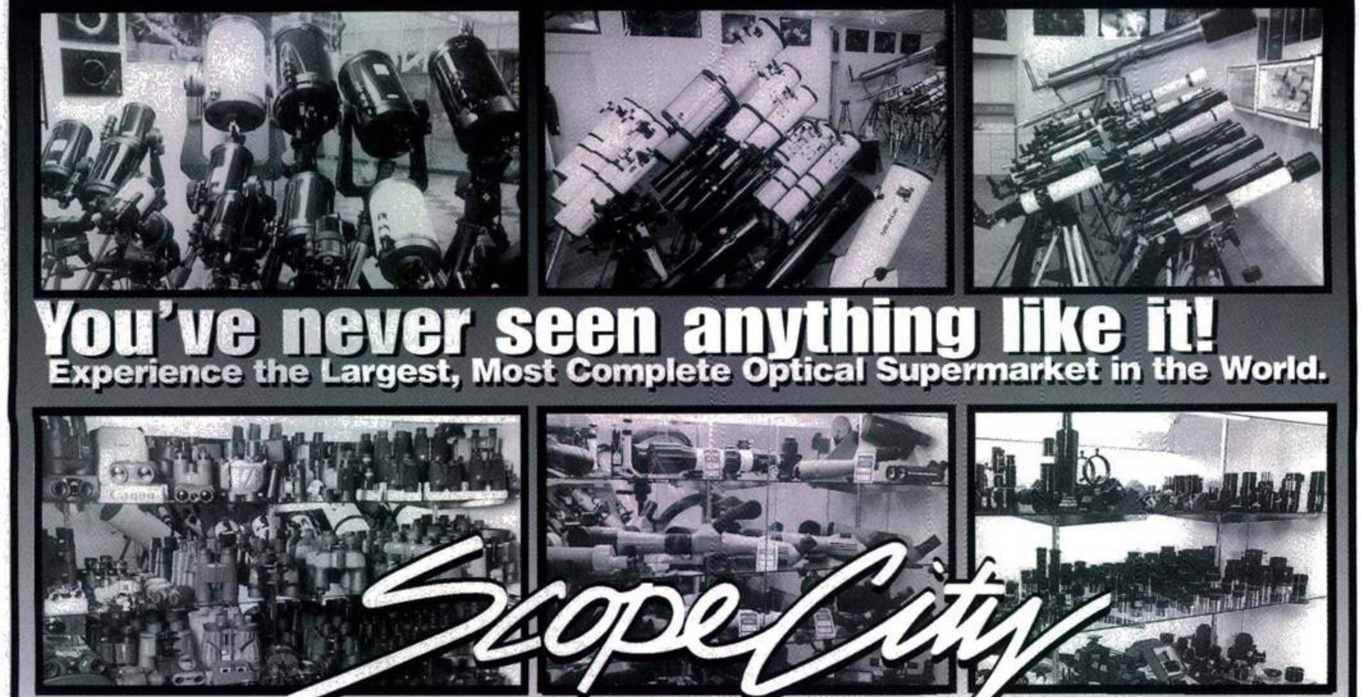

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# OUT OF SIGHT,

*A daring band of astronomers contemplates a universe without dark matter.*

**by Steve Nadis**

*Old habits die hard.* The axiom rings as true for astronomers as it does for the average Joe. Over the years, astronomers have eagerly adopted some pretty strange ideas — a few of them based on hardly more than a wish that nagging problems would go away — and fought hard to hold onto them just the same.

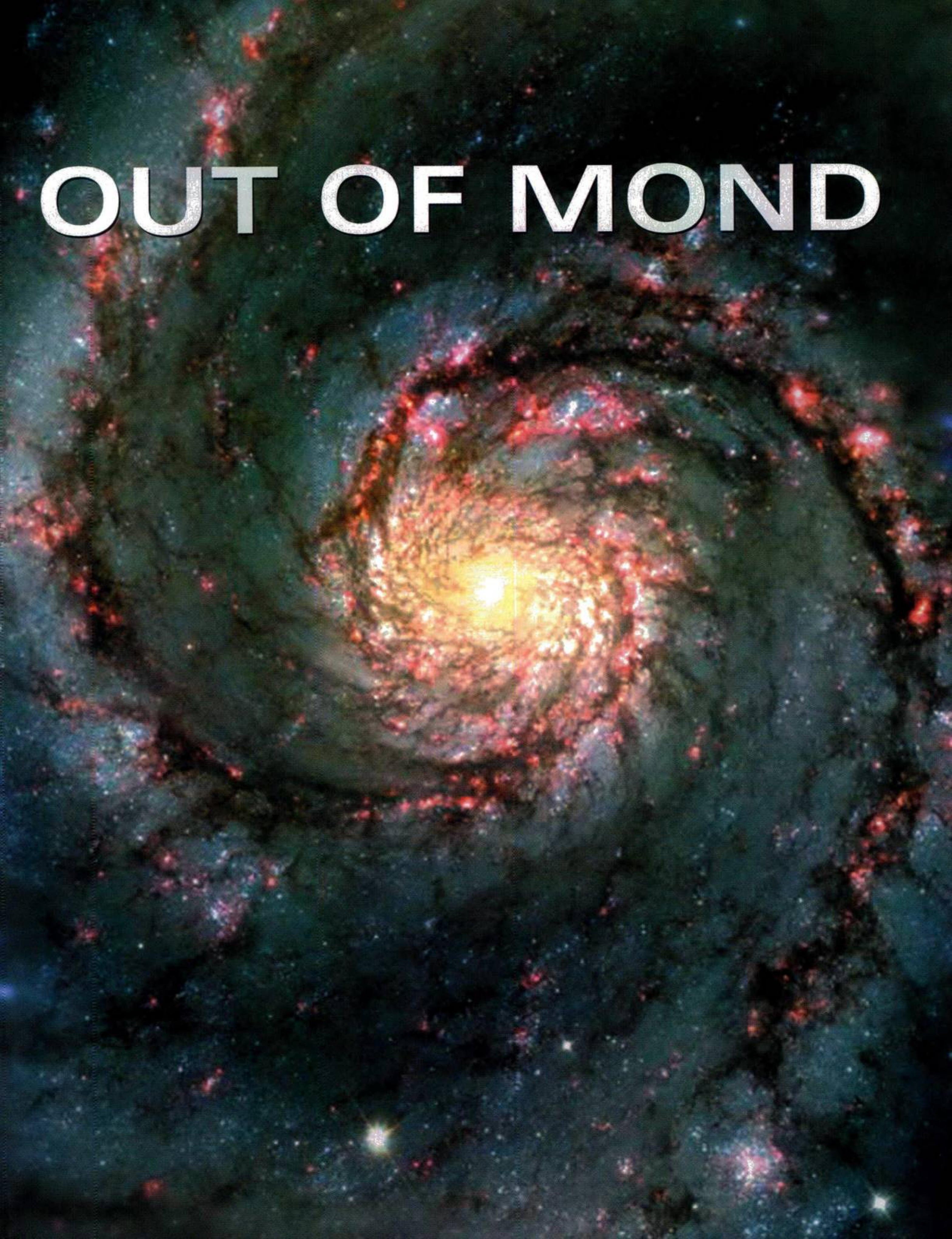
Less than a century ago, party liners insisted that we live in a static universe, contained entirely within the Milky Way Galaxy. And now, most astronomers would almost surely bet the lion's share of their salary that ours is an infinite, accelerating universe, dominated by a mysterious dark energy, full of dark matter, with just a sprinkle of that regular, see-it, touch-it, smell-it stuff that surrounds us.

In the late 1960s, Carnegie Institute astronomer Vera Rubin discovered that stars and gas teetering near the edge of spiral galaxies like the Andromeda Galaxy (M31) were buzzing at speeds up to 10 times greater than could be explained by the gravitational pull of visible stars alone. And in the decades since, all signs point to a ubiquitous "gravitational glue," which binds the universe and prevents galaxies and galaxy clusters from breaking apart.

What's more, astronomers have gone to great lengths to affectionately name, define, and categorize this zoo of invisible stuff called dark matter. There are the MAssive Compact Halo Objects

**Do spiral galaxies like M51 suggest a universe filled with dark matter? Some say yes. Yet others say that it's all just one big misunderstanding.** Hubble Heritage Team (STScI/AURA)/NASA

# OUT OF MOND



(MACHOs) — things like brown dwarfs, white dwarfs, black holes, and neutron stars that purportedly populate the outer reaches of galaxies like the Milky Way. Then there are the Weakly Interacting Massive Particles (WIMPs), which possess mass, yet don't interact with ordinary matter — baryons such as protons and neutrons — because they are composed of something entirely foreign and unknown. Dark matter even comes in two flavors, hot (HDM) and cold (CDM). And all the while, astronomers and physicists have refined their dark matter theories without ever getting their hands on a single piece of it.

**"Maybe it just ain't there."**

But where is all of this dark matter? The truth is that after more than 30 years of looking for it, there's still no definitive proof that WIMPs exist or that MACHOs will ever make up more than five percent of the total reserve of missing dark stuff.

A small band of astronomers persistently asks the question, "Why are all these dark matter searches coming up empty-handed?" Among them, University of Maryland astronomer Stacy McGaugh chooses to take the unorthodox, yet logically conservative position that "maybe it just ain't there."

"One hundred years ago, most astronomers insisted that space was filled with an ether," adds McGaugh. "It turns out we just didn't understand things well enough back then. Ultimately, dark matter may be viewed in the same light."

Still, most astronomers aren't willing to give up on dark matter just yet. At least not without a good fight and a decent alternative.

## ALL ABOARD THE BANDWAGON

Breaking old habits takes more than simple awareness, but at least that's a start. When McGaugh began his career in astronomy in 1992, after earning his Ph.D. from the University of Michigan, he subscribed to the standard doctrine that the cosmos is permeated by CDM — that slow-moving, invisible matter purported to hold galaxies together and aid in the formation of larger structures like clusters and superclusters. Like most of his peers, he paid little attention to theoretical alternatives to dark matter such as MOdified Newtonian Dynamics (MOND), advanced in 1983 by astrophysicist Moti Milgrom, at the Weizman Institute of Science in Israel.

Isaac Newton's laws of motion constitute the basis of Newtonian Dynamics. And it's certainly true that his laws do a pretty good job of explaining gravity and motion on earthly scales. Yet those principles break down on cosmological scales, a fact which prompted Albert Einstein to rewrite Newton's Laws in 1915 with his General Theory of Relativity.

MOND is a subtle modification of Newtonian Dynamics rather than a sweeping new theory like General Relativity. It effectively modifies the force of gravity, making it stronger in very diffuse systems such as the outer reaches of spiral galaxies and galaxy clusters.

Milgrom's MOND holds that, for reasons yet to be explained, Newton's Laws fail in extremely low-density environments. But the added gravitational kick provided by MOND is very small, so that it's only noticeable when gravity falls below one hundred-billionth that experienced on Earth. Because these effects are so subtle, they haven't crept into studies of our solar system, while they may become apparent in regions like the galactic fringe, where matter is spread far and wide.

Although no one can yet say for sure why the laws of gravity might change in low-density, low-gravity extremes, Milgrom and others have plenty of ideas. (One notion is that the modified gravitational acceleration constant introduced by MOND might be related to the dark energy — or cosmological constant as it's sometimes called — that's making the universe's expansion accelerate.) However it works, MOND describes how gravity gets a boost, so that dark matter is not needed to hold galaxies together or to spur the formation of large-scale structures. The universe, according to MOND, is primarily composed of ordinary matter rather than unknown species. Cold dark matter, if it exists at all, would make up only a relatively small fraction of the universe.

## LEARNING CURVES

As a post-doc at Cambridge University in 1994, McGaugh encountered a vexing puzzle while analyzing data on low surface brightness (LSB) galaxies — large, yet faint, stretched-out versions of normal spirals with greater separation between stars. That season he was busily engaged with producing rotation curves — plots of the rotational velocity of galactic material versus distance from galaxies' centers — for these low-density galaxies (see "MOND: A Theory Fit for Revolution," page 29). McGaugh expected to see a marked difference between the rotation curves for these loose assortments of stars and classic spiral galaxies. After all, a larger separation between stars should result in a weaker gravitational attraction and a diminished rotational velocity of galactic material.

To his chagrin, however, the LSB galaxy rotation curves were almost identical to those of familiar spirals. He couldn't make sense of the results, even by tinkering with the amount of dark matter that might be concealed in the galaxies' halos. "I knew something was screwy here," he says.

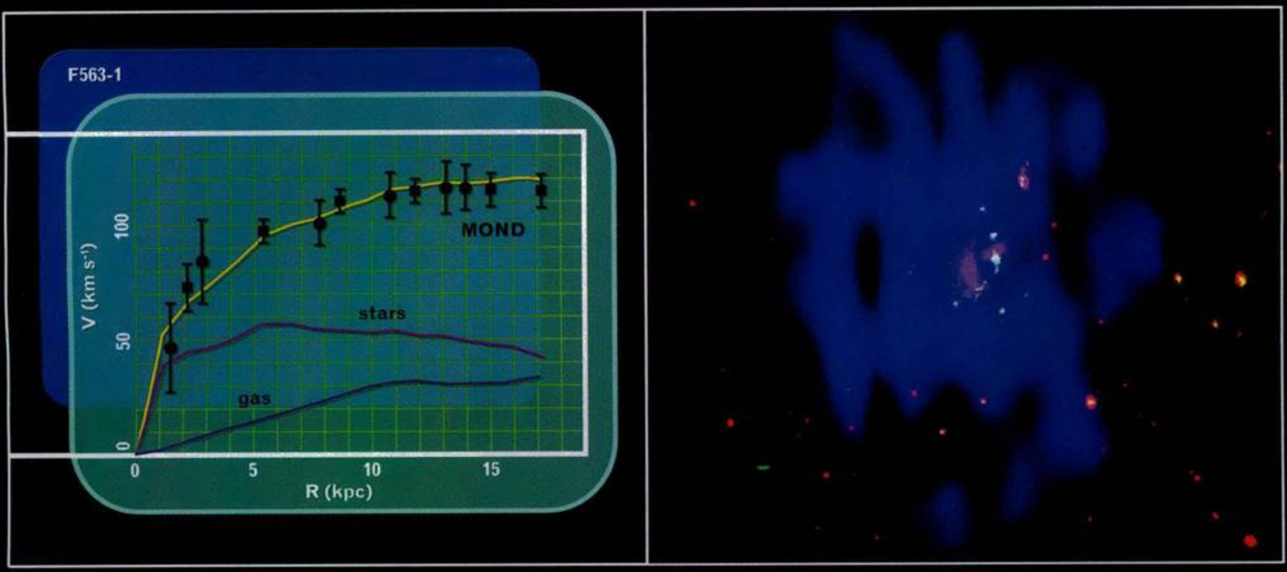
That same year, Milgrom gave a speech at Cambridge in which he

### Stacy McGaugh: Out on a Limb?

It was hard for McGaugh to accept the proposition of a universe without dark matter, which turned his customary way of looking at things upside-down. "The existence of dark matter was well-established by the time I had my Ph.D.," he says. "I didn't pay attention to MOND until it crept into my own data. Then I struggled with the results. I had to do some soul-searching before coming around to the point of view that Milgrom's MOND theory does a better job of explaining rotation curves than dark matter models." — S.N.

Thai Nguyen/UMD

## MOND: A Theory Fit for Revolution



Left: *Astronomy*: Terri Field/Stacy McGaugh; right: Erwin de Blok/Kapteyn Astronomical Inst.

**MOND**'s greatest strength is its ability to reproduce galactic rotation curves, like this one for the **LSB** galaxy **F563-1**. The image of F563-1 on the right is a false-color combination of emission from hydrogen gas and newborn stars, in radio (blue) and optical (green-yellow) light, respectively. Pink and purple lines indicate where the data (black squares and circles) should lie if the stars and gas follow **Newtonian Dynamics**. The yellow line correctly predicts where the data should fall in a **MOND**-ruled galaxy.

described, among other things, the dynamic characteristics of LSB galaxies. After the talk, McGaugh decided to read Milgrom's original 1983 paper on MOND, which featured a detailed section on yet-undiscovered LSB galaxies. But by 1994, McGaugh says, "I had already done the experiment. I had the data, did the test, and basically confirmed all of his predictions. It's amazing when you think of it — making correct predictions about [LSB galaxies] when some astronomers were sure that they didn't even exist."

Modifying scientific laws according to physical scale isn't new to scientists. "Relativity and quantum mechanics were developed to deal with the special cases of what happens when you approach the speed of light and when things get extremely small," McGaugh explains. "Milgrom's MOND theory deals with the case of what happens when accelerations due to gravity become very small."

### FACING THE FACTS

"A skeptical attitude toward MOND is entirely justified," says Milgrom. "Heretical theories should be given a hard time. It still isn't widely accepted, but at least more people listen to our ideas now."

One astronomer who listened early on is Robert Sanders, at the Kapteyn Astronomical Institute in the Netherlands. "I had my own idea for modifying gravity in 1984 that was somewhat different from MOND," offers Sanders. After submitting a technical paper to a European astrophysics journal, he received a long letter from one of the referees, Milgrom, explaining the inherent flaws in his argument. "My paper was published, but I decided Moti was right," Sanders says. "Although MOND is a radical idea — given that scientists still can't say what the dark matter is, don't have a full understanding of gravity, and don't even know where mass itself comes from — there's room for radical ideas."

Sanders and other astronomers have now examined rotational velocities in more than 100 spiral galaxies, and the fit with MOND is astounding, he says. "It's hard to see all these perfect rotation curves and not believe there's something here."

### COSMOLOGICAL SKELETONS

McGaugh firmly believes that MOND fits galaxy rotation curves better than dark matter models. Still, at one time he naively assumed that the papers he published on LSB galaxies with Australian astronomer Erwin de Blok might even clinch the case for MOND, but few astronomers were swayed. "I sometimes ask people, 'What would make you reconsider your position?' They answer, 'Well, if the microwave background did something weird...'"

After pondering this matter, McGaugh published a bold prediction in a 1999 *Astrophysical Journal* paper. He said we should be able to see a "distinctive signature" in the cosmic microwave background, depending on whether the universe's principal mass constituent is CDM or baryons.

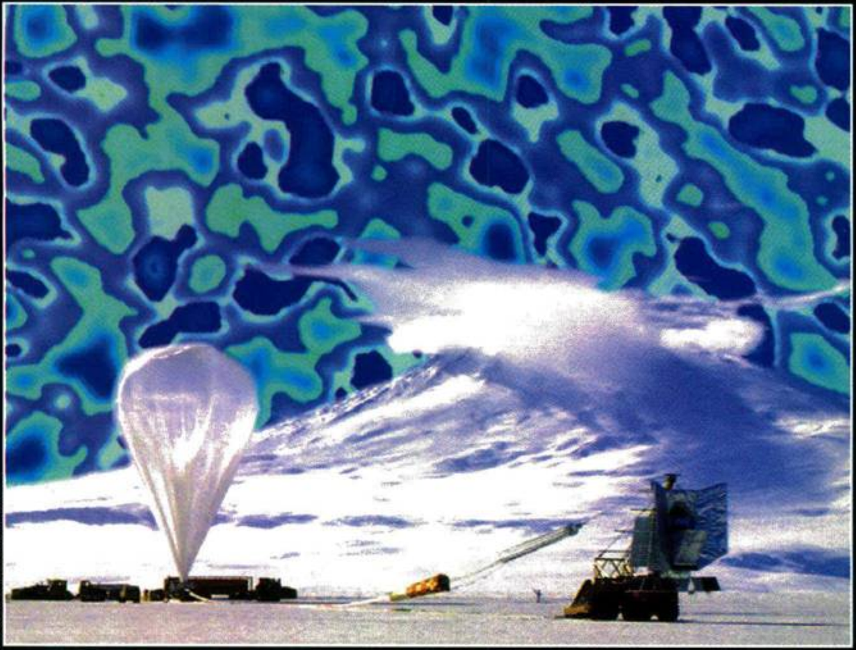
The microwave background provides a snapshot of the universe about 300,000 years after the Big Bang, when light separated from matter and streamed freely into space. Matter in plasma form — as it was before the era of separation — oscillates, creating primordial sound waves that show up as multiple peaks in the microwave background. "The way the plasma sloshes around depends on the form the mass is in," explains McGaugh. Because baryons interact strongly with photons, they act as a drag force that dampens the oscillations so that each successive peak gets smaller. CDM doesn't interact with photons, so that the peaks would take longer to damp down.

Early high-resolution Balloon Observations of Millimetric Extragalactic Radiation and Geophysics (BOOMERanG) measurements of the microwave background from the Antarctic sky revealed a smaller second peak in the microwave background than would be expected in a CDM-dominated universe (see "A Background of Bold Predictions," below). The results, McGaugh argued in a follow-up 2000 *Astrophysical Journal* paper, lend support to the notion of a purely baryonic universe in which MOND could explain the mass discrepancies traditionally ascribed to dark matter. "Cosmic microwave background studies can't tell us for sure whether MOND is right," he says. "They are just a test for the presence or absence of CDM. But if CDM doesn't exist, you need something like MOND to explain the observations."

### MOND IN THE MEANTIME

Over the course of several years, Jacob Bekenstein of the Hebrew University in Jerusalem has worked to extend the General Theory of Relativity to incorporate MOND. He is optimistic

## Breaking Debate: Peaks in the Background

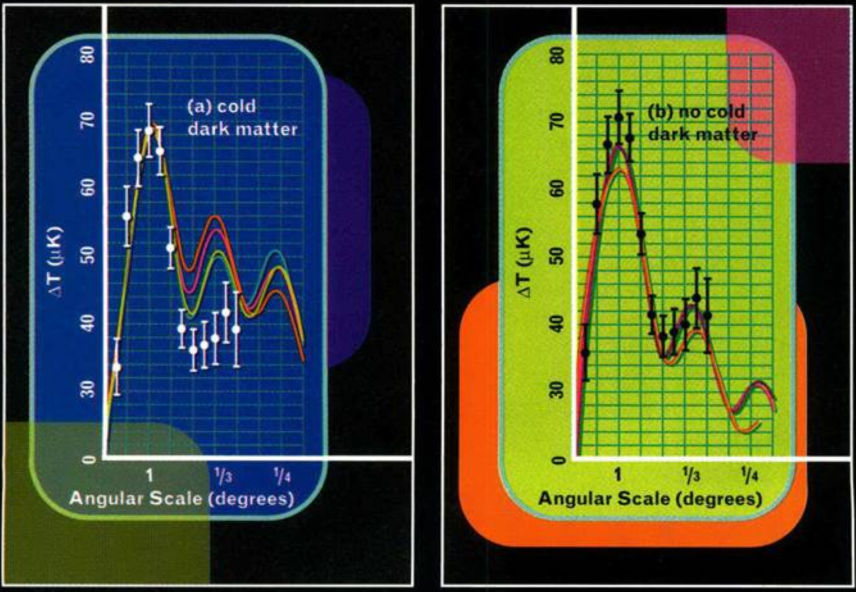

BOOMERanG Collaboration

**A late-breaking, multi-study measurement of acoustic peaks in the microwave background (signatures left over from the creation of matter) reportedly bolsters evidence that exotic dark matter is at least eight times more abundant than ordinary matter. Could this finally be the death knell for MOdified Newtonian Dynamics (MOND)?**

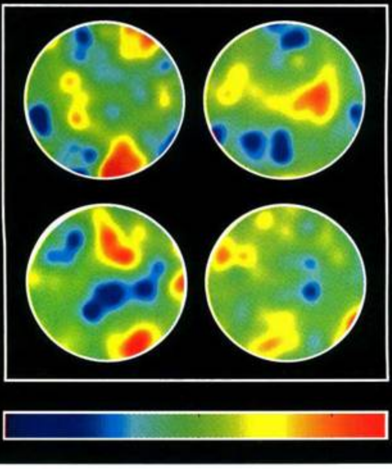
**"Not so fast," says University of Maryland astronomer Stacy McGaugh, who is admittedly partisan on this issue. "We won't be able to make a clear-cut judgment between cold dark matter (CDM) and MOND until somebody makes accurate measurements of the first three acoustic peaks." CDM theory predicts a larger third peak than the second, whereas MOND predicts a smaller third peak.**

**Although two background-spying teams have claimed detection of a third acoustic peak, it's still too early to say which way the pendulum will swing. "I fear that a definitive measurement of the third peak will have to await the launch of the Microwave Anisotropy Probe (MAP)" — an ambitious space-based cosmic background experiment scheduled to launch later this year. — S.N.**

## A Background of Bold Predictions



**In 1999, McGaugh made a daring prediction for what microwave background observers would find if cold dark matter doesn't exist. BOOMERanG results from early 2000 reveal the best fit with contrasting theoretical predictions — for a universe full of cold dark matter (a), and a universe ruled by MOND (b).**


DASI Collaboration

that such a theory can be established, "but whether a complete, relativistic MOND would agree with nature is still anybody's guess," says Bekenstein.

The goal, according to Milgrom, is to develop "a theory that at one limit of very high acceleration gives you general relativity and at the other limit of very low acceleration gives you MOND." "We know that MOND has to be extended, in the same way that quantum mechanics has to be extended to achieve a theory of quantum gravity," explains Milgrom. "But that doesn't mean we can't continue to use MOND in the meantime."

Both Sanders and McGaugh have tried their hand at seeing how cosmology and structure formation might work in a universe where MOND, rather than dark matter, reigns supreme. Though it likely didn't play a prominent role in the earliest epochs when the universe was dense, MOND could play a powerful role during later epochs, when the universe cooled to the point where matter began to dominate over radiation.

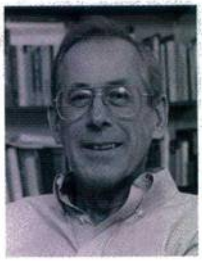
"You need to give gravity a kickstart so that structures like galaxies can grow from tiny mass density fluctuations, which is why WIMPs were proposed in the first place," says McGaugh. "But that's all based on the assumption that gravity is normal."

If gravity is somehow enhanced in very diffuse systems, growth can happen faster. "We've just invented a different tooth fairy to explain the formation of structure," he adds.

"This scenario is really anathema to most cosmologists," admits McGaugh. "It's an issue where you tend to get strong reactions."

**"It's an embarrassment that the dominant forms of matter in the universe are hypothetical."**

## Viable Alternatives



Princeton University cosmologist Jim Peebles agrees that it's reasonable to consider MOND as an explanation for the 2000 BOOMERanG collaboration results. "It's an embarrassment that the dominant forms of matter in the universe are hypothetical," Peebles admits. "At the moment, MOND is the only viable alternative to Cold Dark Matter (CDM) models that I've seen. But more moderate explanations are possible too," he adds.

Peebles and University of Maryland astronomer Coleman Miller have independently offered another explanation for the small second peak in the BOOMERanG data without resorting to MOND. They propose that some yet-unidentified ionization sources might have interacted with photons sometime after the decoupling of light and matter. "These interactions would suppress the second and later peaks in the microwave background, while leaving the first peak unaffected," says Miller.

Miller thinks these ionization sources could be primordial black holes. "The radiation released by these objects would ionize atoms, releasing free electrons that would scatter the cosmic background radiation," he adds. — S.N.

### A HARD SALE FOR SOME

CDM theorist and physicist Michael Turner, with the University of Chicago and Fermilab, is one of MOND's more vocal critics. "Milgrom made a brilliant observation that the need for dark matter kicks in at a certain acceleration scale, rather than at a certain distance scale," he says. "That provided astronomers with a hint that there might be something wrong with gravity. But that hint still hasn't produced much. MOND has no predictive value. It can't tell us, for instance, how galaxies should bend light."

"Richard Feynman used to say you know you're on the right track with a new idea if you put in 15¢ and get $2 back," Turner adds. "With MOND, you put in $1 and get $1 back."

Milgrom doubts that a single breakthrough — either from the theoretical or observational end — will prompt astrophysicists to embrace MOND en masse. "Science really doesn't work that way," he says. "It's almost never something drastic, like a dramatic discovery, that leads to the acceptance of a new theory. It normally takes awhile, happening gradually, as it has over the past 18 years."

### EXTREME SOLUTIONS

Rubin, who also collaborates with McGaugh and de Blok on studies of LSB galaxies, believes the data is still not good enough to discriminate between dark matter and MOND models. "History suggests that anything you can do with dark matter, you can also do with MOND. But I'm impressed that after about 30 years, no one has been able to knock out MOND or discover dark matter. The longer this goes on, the more people will be open to other interpretations."

While theorists are hard at work, trying to explain a physical basis for MOND, observational astronomers are studying a variety of systems. In addition to spiral and LSB galaxies, they may study galaxy clusters, large-scale filaments, and the like to see if their behavior is consistent with MOND. More clues will come from cosmic background radiation experiments, particularly the Microwave Anisotropy Probe (MAP) mission, which will probe the entire sky with a resolution comparable to what the BOOMERanG collaboration obtained for a tiny patch measuring about one square degree.

McGaugh has no idea how things will turn out. "Both views, MOND and cold dark matter, require big leaps," he says. "Changing the force law seems like a bigger leap, but maybe that's because we're already used to the other leap. Sometimes extreme problems require extreme answers."

McGaugh is thankful that most of the galaxy work he does is useful for assessing both dark matter and MOND scenarios. "Of course, if things go well with MOND, it will make me a popular guy," he says. "On the other hand, if dark matter is discovered directly, I'll probably spend the rest of my career trying to figure why MOND does such a good job of predicting things that cold dark matter is responsible for." ■

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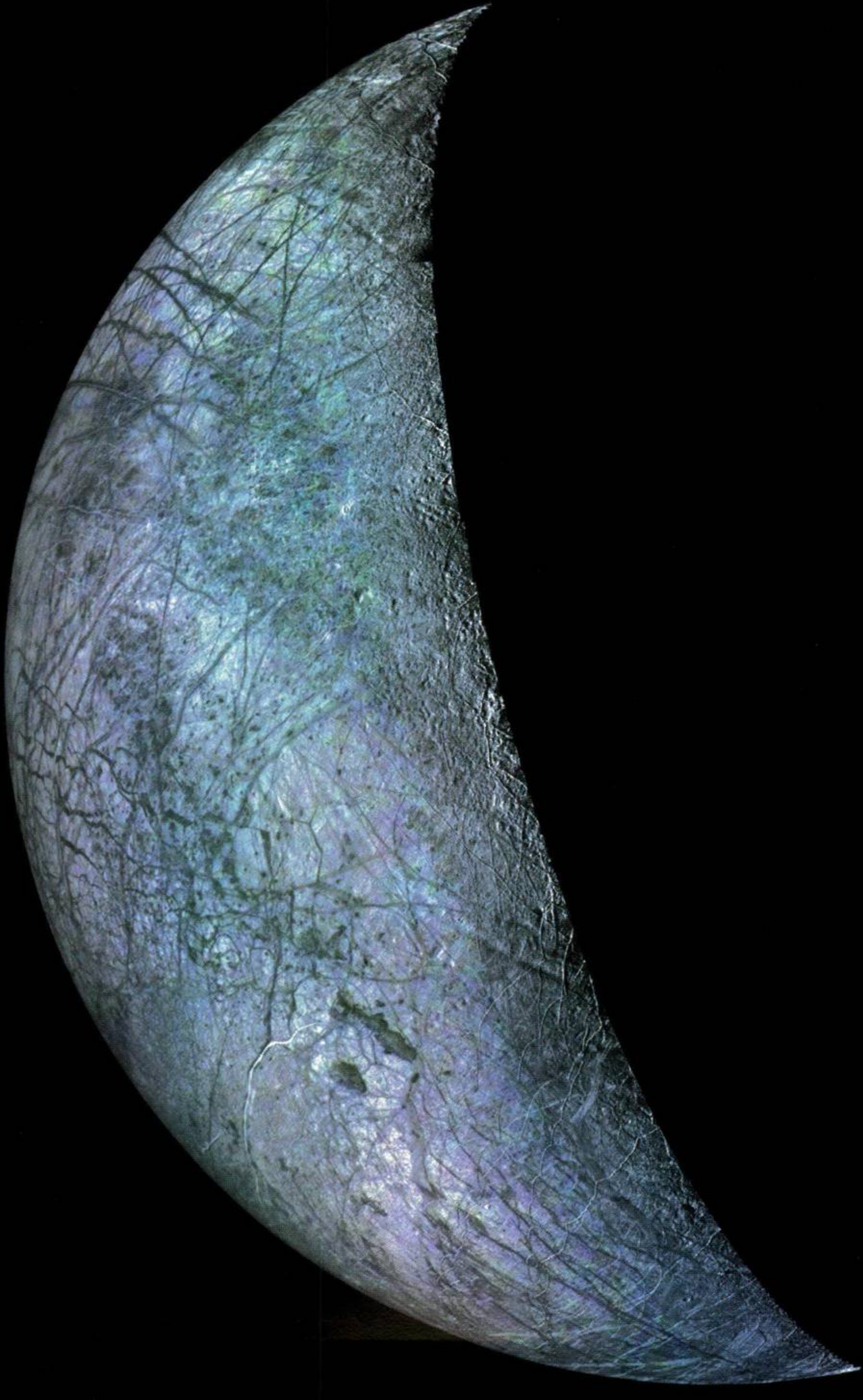
*Steve Nadis is a freelance writer based in Cambridge, Massachusetts. His latest article for* Astronomy, *"Here, There, And Everywhere?", appeared in the February 2001 issue.*



# IS THERE LIFE...

Exploring Europa is a top priority for NASA planners
because the ocean below its icy crust,
or even pockets in the ice, may harbor life.

**by Dana Mackenzie**

DECEMBER 31, 2010: *It has been a daunting voyage to the second of the four jovian moons Galileo discovered four centuries ago. Launched in 2007, the Europa Orbiter spacecraft has traveled half a billion miles, chasing a dot of light whizzing around Jupiter at 30,000 miles per hour. Last week, it maneuvered out of Jupiter's gigantic gravitational hug and sidled into Europa's gentle embrace.*

*The orbiter's color-enhanced pictures of what looks like a scuffed-up orange billiard ball with white polar patches are the sharpest ever seen of the object, which is about the same size as Earth's moon. The dark and salty waters of our solar system's largest ocean may circulate under Europa's cracked and wrinkled surface. Nobody knows the ice's thickness, the depth of water underneath, or whether the ocean contains life. As Europa Orbiter begins transmitting data this week, the final week of 2010, it may mark our first exploration not merely of another planetary body, but another living biosphere.*

**Europa's lacework pattern of fractures and faults etched across its surface provides planetary scientists with many clues about this semifrozen world.** NASA/JPL/USGS

# UNDER THE ICE?

In 2001, of course, the Europa Orbiter is still a dream — merely drawings on the whiteboards of the Jet Propulsion Laboratory (JPL) in Pasadena, California, the main contractor for the mission. But the satellite of Jupiter is one of NASA's highest priority targets in the outer solar system. Aquatic life thrives on the floors of Earth's oceans, sustained by upwelling chemical nutrients from the planet's interior. If an ocean exists on Europa, it would be reasonable to speculate that life could also exist, possibly near undersea volcanic vents.

Originally expected to launch in 2003, the Europa Orbiter is on track for launch in 2007 and arrival by 2010, marking the 400th anniversary of Galileo's discovery of Europa and its three neighboring moons — Io, Ganymede, and Callisto. And it also is the date of Arthur C. Clarke's *2010*, the sequel to *2001: A Space Odyssey*, in which Europa plays a key role.

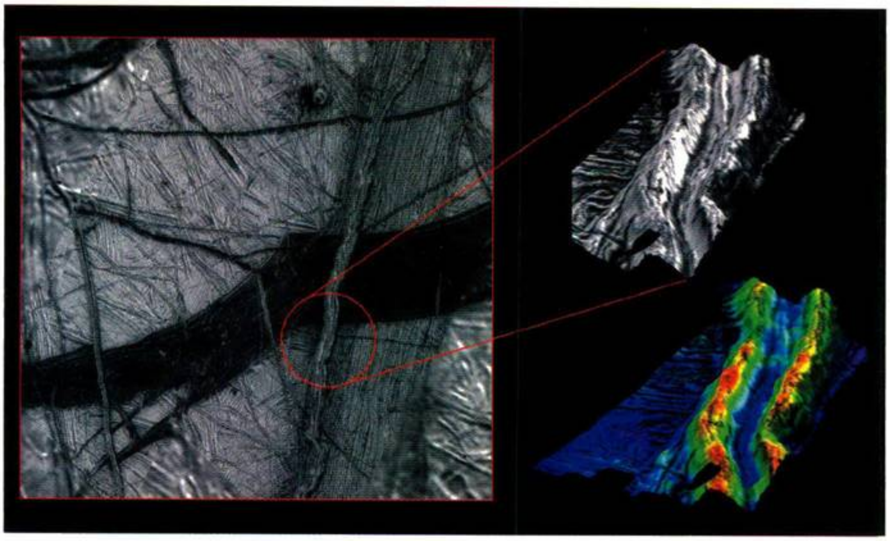
## UNDER STRESS

Before the Voyager missions gave us our first close-up view of Jupiter's satellites in 1979, Europa was just another icy moon, an asterisk in Galileo Galilei's astronomical drawings. But Voyagers 1 and 2 revealed that Europa differed greatly from the other Galilean moons.

Ganymede and Callisto looked similar to our own moon, pockmarked with craters. Io turned out to be a sulfurous, volcanic cauldron. But Europa's surface looked as if Zamboni machines were constantly resurfacing its icy crust; it has very few craters. Instead, it is crisscrossed by thousands of reddish stretch marks.

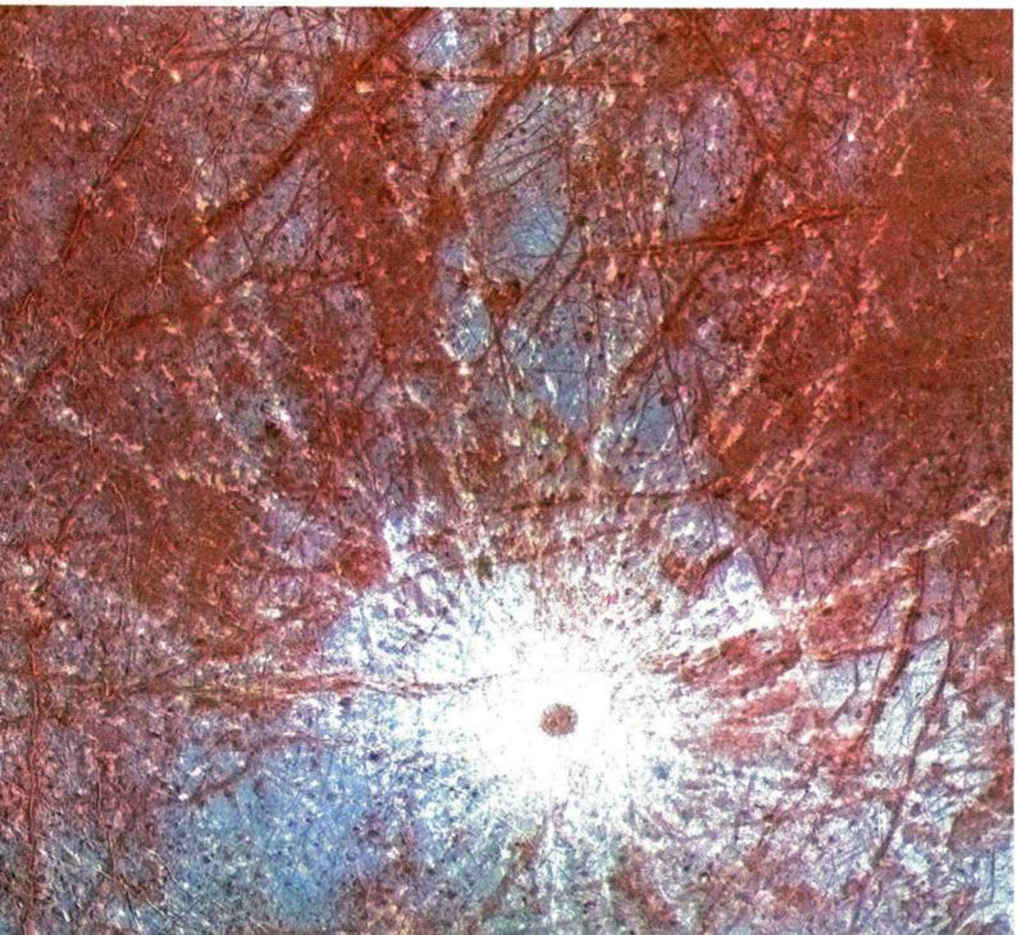
These marks suggest that tidal stresses are melting Europa's ice from within. Both Europa and Io stretch and relax like rubber balls each time they move toward Jupiter and away; this flexing warms them. On Io, the warming vaporizes water and gives rise to constant volcanic eruptions. On Europa, which is farther away from Jupiter, the stretch-induced heating is gentle enough to permit liquid water covered by ice to exist.

The Galileo spacecraft gathered evidence for an underground ocean on Europa after it began orbiting Jupiter in 1995 and photographing its moons. The images showed "chaos regions," where jumbles of large ice rafts resemble Antarctic floes that have broken up and refrozen. Galileo delivered an unexpected finding last year: An instrument aboard the spacecraft detected variations in the moon's magnetic field that show that Europa is a SeaWorld beyond our world. (Ganymede and Callisto are also believed to contain oceans, under a much deeper layer of ice than that covering Europa.)



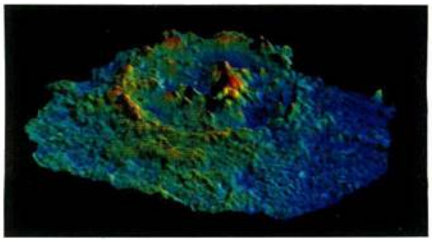
**Top: This 3-D perspective of a europan double ridge shows water ice on ridge crests and silicates or salts on the valley floor.**

NASA/JPL/DLR

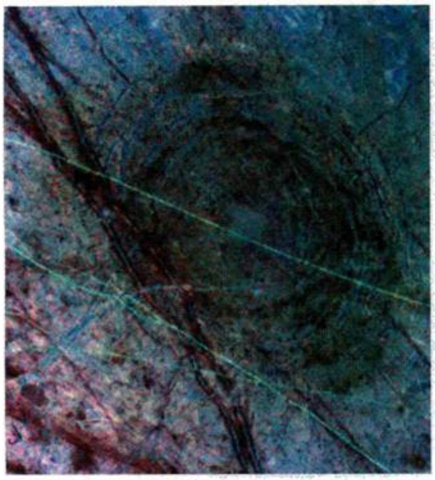


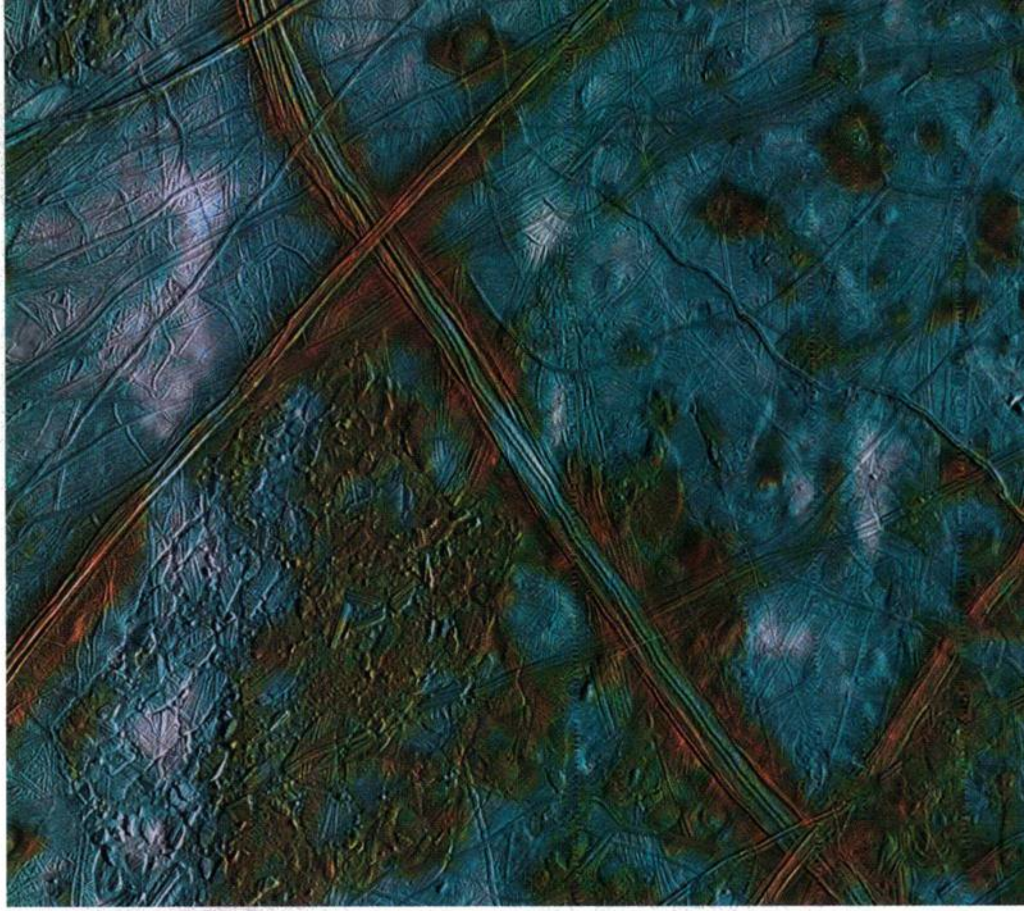
**Left: This is the young impact crater Pwyll, which is 16 miles (26 km) in diameter.**

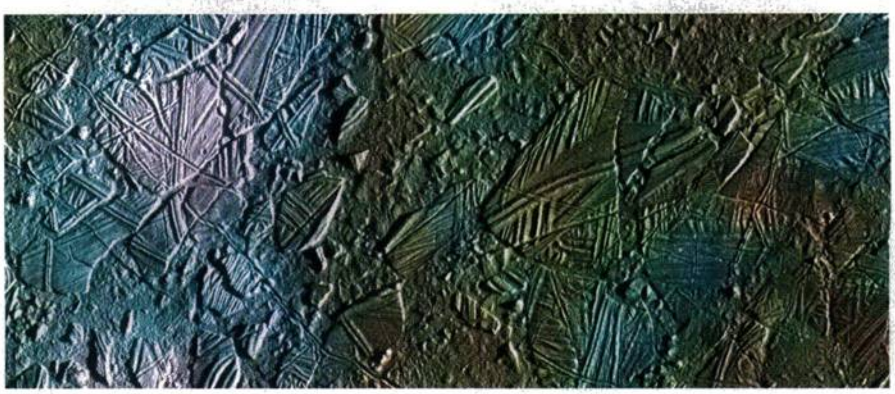
NASA/JPL/PIRL/U. of Ariz.



**Bottom: In this 3-D image of Pwyll, the central peak (red) is 2,000 feet (600 m) above the floor (blue).** NASA/JPL/DLR







**Top: This 86-mile (140-km) impact scar was caused by a mountain-sized asteroid or comet.** All three images: NASA/JPL/PIRL/U. of Ariz. **Right: The white areas are ejecta rays from Pwyll, the reddish areas correspond to non-water ice, and the old icy plains are blue. Bottom right: This photo shows thin, disrupted ice crust in Europa's Conamara region.**

Could Europa's SeaWorld harbor life? At first, scientists believed the ice was up to 100 miles thick. But some planetary scientists argue that the chaos regions on Europa suggest that the ice may be as thin as one mile, and it may have been breached with slushy geysers or shaken by daily "Europaquakes."

Once thought to be devoid of sunlight or other sources of energy, Europa may have warm spots under its ice that support periodic "blooms" of microscopic life. Depending on whom you talk to, Europa has become our best or second-best hope for finding extraterrestrial life in our solar system. The Galileo spacecraft has given us a much better understanding of Europa's environment — but astrobiologists wonder if the place is too inhospitable for life of any form.

## EXTREME EXPLORING

For example, the surface of Europa is the ultimate extreme environment. Its surface temperature is a chilly –240° F (–151° C). Intense radiation, including charged particles such as electrons, protons, and sulfur ions, constantly bombard the satellite. Io produces the chemically reactive particles, which become trapped in Jupiter's magnetic field and create aurorae in the jovian atmosphere. Because Europa has only a very thin atmosphere, the particles zip nearly unimpeded into its surface at 40 miles per second. Particles traveling at that speed would cause serious damage to any life-form. "It's like being 30 feet from the core of a 100-megawatt nuclear reactor," says JPL's Richard Terrile, chief scientist for NASA missions to the outer planets. The radiation would fry unshielded electronics. "It would kill an astronaut in an EVA suit in 12 minutes," he says. "The Europa Orbiter arguably is the most difficult mission NASA has ever attempted."

Anything that lands on Europa will be able to appreciate the icy view only briefly. Robotic landers or astronauts would have to burrow into the ice like moles for protection. Surprisingly, even three feet of ice would provide an excellent shield against Jupiter's invisible barrage of charged particles. At this safe depth, human or robotic explorers could sample Europa's chemistry and look for freeze-dried microbes. Europa is a candy store for chemists: To sample what's there, they would simply scoop up ice and melt it. They could concentrate samples, purify them, and even examine them under a microscope — a first for a deep-space mission.

Any explorer would find the satellite's brightly lit surface a snowmobiler's paradise. With a tenuous atmosphere, it never snows on Europa; however, meteorites have likely struck the surface often enough to create a 2-foot-thick layer of debris. "We may find ourselves up to our chins in very fluffy ice," says Eric Gaidos, a JPL geobiologist.

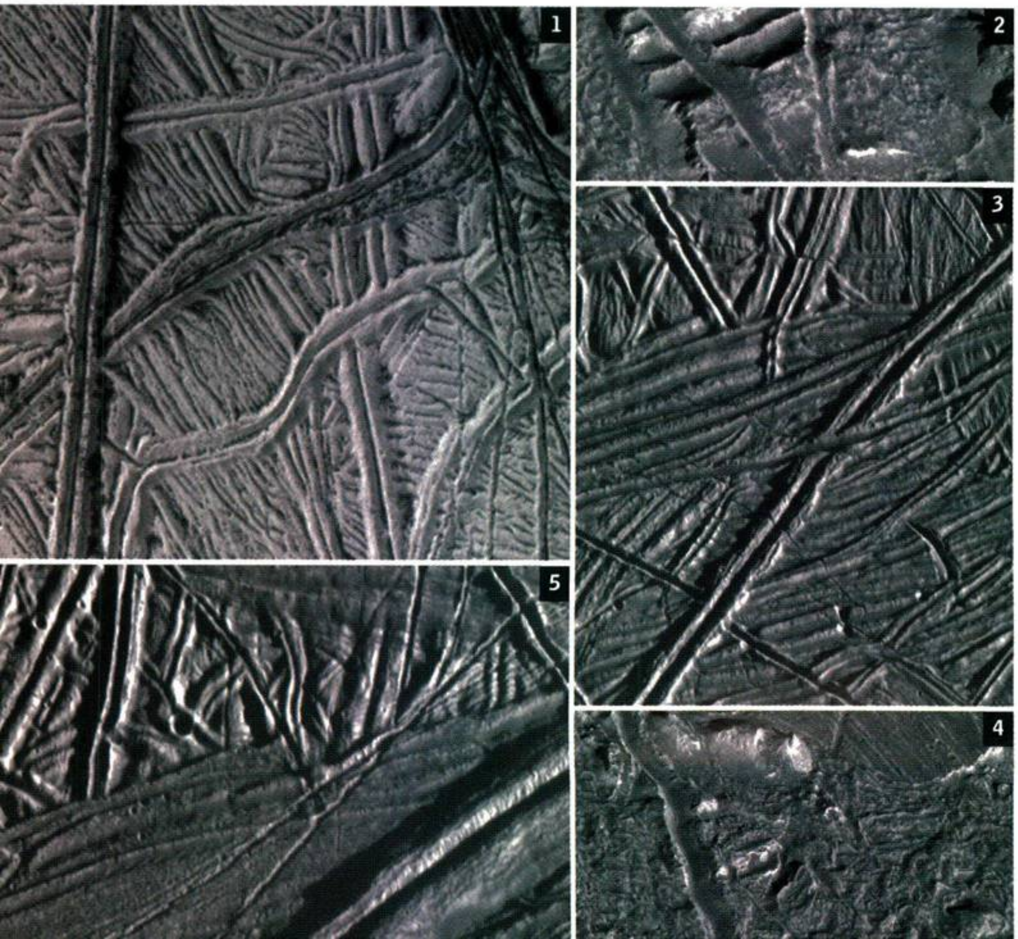
The explorers may also encounter

the mysterious substance that gives Europa its lemony hue. Spacecraft-instrument readings suggest that the colored material could be magnesium sulfate, Epsom salt that yellowed in the intense radiation, sulfur, or sulfuric-acid ice. Whatever it is, it may have welled up from Europa's ocean, providing a wealth of information about the environment below.

Overhead, Jupiter will loom over the explorers like a brightly striped beach ball — unless they land on the farside of Europa, in which case they will never see the giant planet. Just as only one side of our moon faces Earth, Europa is tidally locked to Jupiter.

If we were extremely lucky, our lander might witness a "cryovolcanic" eruption. Planetary scientists think liquid carbon dioxide squeezed under high pressure through cracks in the ice power these dramatic events. Like opening a well-shaken can of soda, the liquid carbon dioxide would bubble explosively upon reaching the surface. "You'd get a spectacular geyser," says David Stevenson, a physicist at Caltech. "The exhaust velocity of an eruption like that would fire material about 60 miles up, because of Europa's weak gravity." The geyser would be a temporary, though spectacular, snow-maker — water in the spray would freeze on the way up, and fall as snowflakes or hailstones. It would be a gorgeous sight, but also dangerous since there is no atmosphere to slow the hail down. No one knows how often — or if — such eruptions occur.

**1. When the sun is high in Europa's sky, its ridges appear more frost-covered. 2. Europan ice cliffs are comparable in size to those at mount Rushmore, South Dakota. 3. Younger fractures cut older ones and horizontal movement indicates fault lines. 4. The broken ice in this chaos region has moved around and rotated. 5. Ridges and fractures crisscross this 9-mile by 5-mile region.** NASA/JPL



## CREEPING CRACKS

A lander would more likely witness the formation of new cracks. According to Gregory Hoppa, a planetary scientist at the University of Arizona, these cracks result from the tides in Europa's ocean. These tides would make those of Miami or Tokyo seem piddly. Tides on Europa would make the crust rise and fall 100 feet during one of its 85-hour days. Though the motion would be too gradual for astronauts to feel, it would crack the brittle ice.

On Earth, a spreading crack on a frozen lake moves fast enough to sound like a gunshot. But on Europa, cracks would creep so slowly through the thick ice that an astronaut on foot would be able to keep up with them. The crack would change directions as the day proceeds. Responding to the changing direction of the tidal stress, the cracks would trace scalloped ruffles across the jovian satellite.

With no atmosphere to carry sound, cracks would open and close in silence, but an astronaut would feel them — especially those due to Europaquakes created when blocks of ice suddenly shift. In the past year, researchers have found that some of Europa's cracks are fault lines, some as long as the San Andreas Fault in California. "Over the course of a day, the crack opens, then it shears, then it closes again, then it tries to shear back," says Richard Greenberg of the University of Arizona and the Galileo imaging team. "But it doesn't go anywhere, because that second shear comes as it is closed. We call this process walking, because it's exactly what you do when you walk."

Greenberg and Hoppa believe that the layer of ice is thin enough — perhaps less than one mile — to crack all the way through. Their thin-ice hypothesis is based on observations that show roughly 18 percent of Europa has large chunks of frozen crust that have been disrupted, tilted, and rotated. Many scientists think these chaos regions are the result of a thin crust of ice floating on a layer of moving water or slush. In this case, Greenberg says, "The biosphere extends right up to the surface."

Other experts think Greenberg is on scientific "thin ice" for various reasons. For example, the 16-mile-wide crater Pwyll, one of Europa's few conventional moonlike features, apparently did not break through the surface. To take such a hit and not break through to the fluid below indicates to planetary scientists that the ice must be 6 to 12 miles thick. In this view, the Europaquakes occur only in an upper brittle layer of extremely cold ice, which rests on a thicker layer of warmer, more-flexible ice. Still, Stevenson cheerfully concedes, "These kinds of things are not easy to predict. It's healthy to have a diversity of opinions, because it means that probably somebody will be right."

The thickness of ice matters a great deal for the likelihood of life on Europa and how we would go about looking for it. Thick ice wouldn't rule out the possibility of life, but it would make life there more difficult to sustain because life requires energy as well as water. "Replication and repairing oneself, all these functions of life are energy-consuming," Gaidos says. "When we talk about Europa we also have to think about what the energy sources are going to be."

A thick layer of ice would isolate europan life from its two biggest energy sources: sunlight and radiation from Jupiter. Photosynthesizing microbes near the surface could use sunlight. Radiation could produce reactive chemicals like hydrogen peroxide, a potential energy source for organisms. In the thin-ice model, these energy sources would be available.

## LIFE IN NICHES

In the thick-ice model, europan organisms could use geothermal energy — the type of energy that powers deep-sea-vent communities on Earth. However, in a pessimistic assessment published in 1999, Gaidos argued that geothermal energy alone cannot fuel a biosphere on Europa. And even on Earth, deep-sea organisms depend on chemicals produced by photosynthetic organisms at the surface of the ocean, says Gaidos.

However, he has changed his mind in the past year, because of a newly discovered fourth energy source — fault lines. Using the thick-ice model, Gaidos has calculated that friction between ice plates could lead to a "thermal runaway" in the fracture zone. The heating would be sufficient to melt ice and create pockets of brine within 300 feet of the surface. These hypothetical structures are similar to brine pockets in Arctic Sea ice inhabited by algae. Organisms on Europa could, in theory, "bloom" in these pockets while the fault was active, then become dormant for millennia until the next fault formed. If so, life on Europa suddenly seems easier to find.

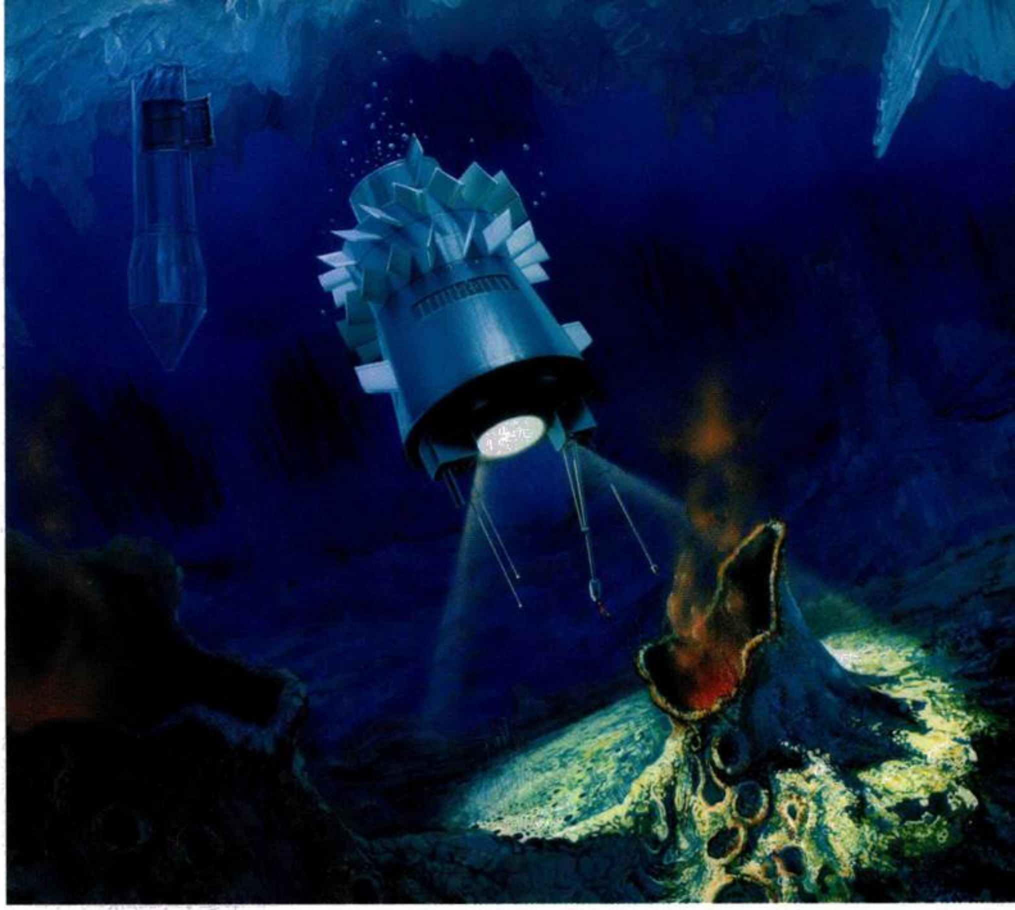
For several years, scientists have thought a planetary probe would have to melt or drill through miles of ice, a huge project that would probably have to wait until the next generation of scientists. But if Gaidos is right, the probes may only need to drill down a few hundred feet.

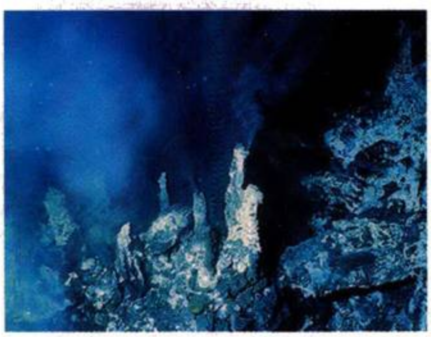
Prior reconnaissance and the ability of a burrowing probe to find and maneuver toward active fault zones would be needed to reach brine pockets. The new proximity of niches for life also argues for greater caution. Nobody knows whether life has evolved on Europa, but microbes carried from Earth by a spacecraft could conceivably contaminate Europa. Greenberg imagines the jovian satellite as pristine — an "open sore" that could be infected if explorers are careless. In Arthur C. Clarke's *2010*, a mysterious alien race forbids us from landing on Europa, presumably because a different form of life is brewing there. Few, if any, scientists want Europa to be declared off-limits, but they are taking the concerns of people such as Clarke seriously. Greenberg contends that NASA does not yet have a non-contamination policy appropriate for such a vulnerable ecosystem.

There may or may not be life on Europa, but no planetary scientist can rule it out. "In my opinion, it's considerably less likely than life on Mars," says Stevenson. "But even though life on Europa may be less likely, it is potentially more interesting, because it's so different." Evidence of water in Mars's past has, in Stevenson's opinion, made the existence of life on that planet more probable.

But if so, it may consist of microbes that hitched a ride from one planet to the other eons ago on a meteorite. In Terrile's words, "We've exchanged spit with Mars." Enough martian rocks to fill an Egyptian pyramid have reached Earth as meteorites since the beginning of the solar system, and some rocks from Earth that were ejected during impacts may have reached Mars.

On the other hand, Europa almost certainly has been isolated from both Earth and Mars since all of them formed. Says Terrile, "That makes it an incredibly important laboratory for understanding whether life arose independently of life on Earth." ■





**JPL has proposed the Europa Ocean Explorer (top) to search under the ice, where black smokers similar to those on Earth (left) may be found.** JPL

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*Dana Mackenzie is a freelance science writer based in Santa Cruz, California.*

# what's WATER got to do with it?

*A deceptively simple molecule is a mysteriously potent wellspring for new stars and terrestrial life.*

**by William Speed Weed**

It's in rain, rivers, and frozen in comets. It's in spinach, caribou, and maple syrup. It's even in you. It should also be in every extraterrestrial creature we might hope to find, and for this reason water has long been a portentous target in astronomical investigations of the firmament.

But water's importance is greater still. Far greater. In fact, it's transcendent, which is why religions have sung its praises for millennia. Astronomers are adding their voice to the chorus of admirers after discovering that the fluid that covers our planet and fills our cells also plays essential roles in the formation of stars and solar systems.

Unfortunately, astronomers can't find a spigot in the sky from which to draw answers to questions about the cosmic tonic. For example, no one knows how water first formed, how life in our solar system sprang from it, or how it provides the precise environment

*Astronomy:* Carol Ryback

our cells require. "Water is a deceptively simple molecule," says David Neufeld, an astronomer at Johns Hopkins University in Baltimore, Maryland, who studies water in interstellar clouds. "For all of water's importance, we actually know remarkably little about it."

Where did $H_2O$ come from in the first place? Cosmologists tell us that the nuclei of the three smallest elements — hydrogen, helium, and lithium — formed about 200 seconds after the Big Bang. But heavier elements, such as oxygen, were fused from lighter elements inside the first generation of stars. We cannot yet see far enough in space — therefore far enough back in time — to study these first-generation stars. However, theorists agree that after oxygen atoms formed, they immediately combined with pairs of hydrogen atoms. "Hydrogen was already everywhere," notes Stanford University chemist Richard Zare, "and once you have oxygen, the most stable thing you could ever end up with is water. There are other combinations of hydrogen and oxygen, such as $H_2O_2$ (hydrogen peroxide), but they're not nearly as stable."

SWAS

**The Submillimeter Wave Astronomy Satellite is detecting water throughout the cosmos.**

Astronomers are using the Submillimeter Wave Astronomy Satellite (SWAS) — which was launched by NASA in 1998 — to understand where and how water forms and distributes itself in the universe as we see it today. SWAS was designed to test ideas about water's abundance in the interstellar medium by examining cold gas clouds, which are so rarified that water exists within them in the gas phase even though the temperatures are frigid.

Unfortunately, this dark, distant water vapor is hard to detect. Water molecules reveal their presence by emitting photons in the submillimeter range of the electromagnetic spectrum. Unfortunately, ground-based telescopes can't see this radiation because it can't penetrate Earth's atmosphere. After its launch, SWAS quickly detected water's photons in clouds heated to 80° F (27° C) as they begin to collapse into stars. "Most of the water we've seen is forming at incredible rates in these star-forming regions," says Gary Melnick, an astronomer at the Harvard-Smithsonian Center for Astrophysics and the principal investigator of SWAS.

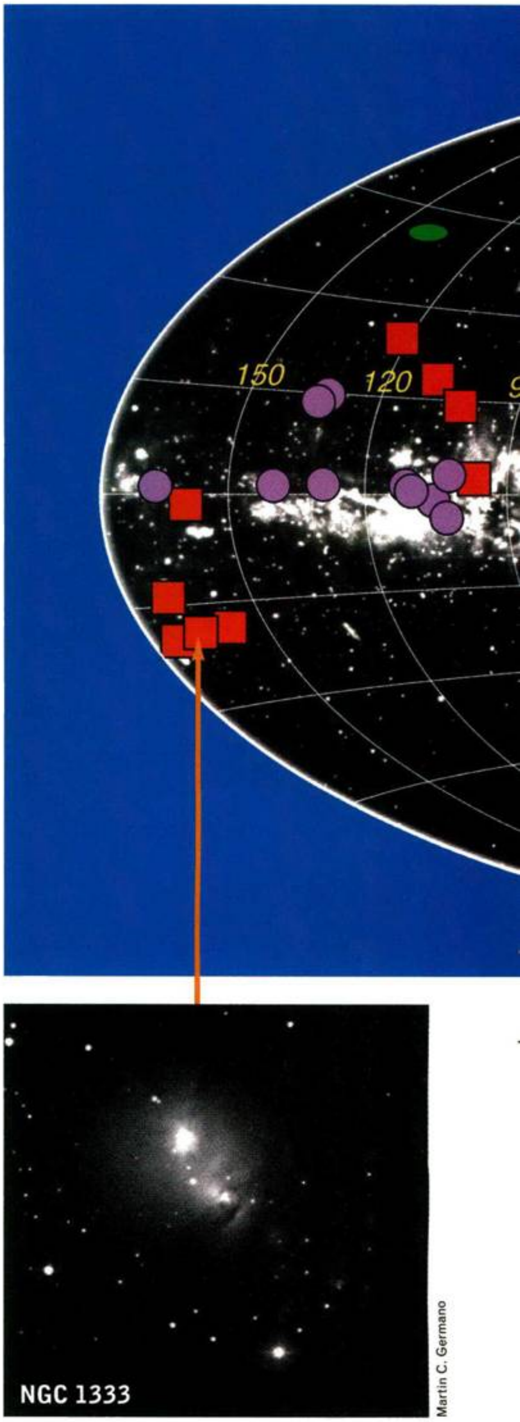
The shock waves from the infant stars are thought to supply the energy required for atomic oxygen to combine with hydrogen. According to Melnick, the reaction is so efficient that a single cloud in the Orion Nebula makes enough water to fill Earth's oceans every 24 minutes. Such a cosmic gusher is a good thing for stars too, because they need a splash of water to radiate heat and keep their cool. A collapsing cloud of hydrogen heats up so quickly that it can blow apart before it forms. As a slightly wet cloud collapses, heated water molecules radiate photons, which allows star formation to continue until the star is born.

However, a deeper mystery lingers: How did the first stars form when space was dry? "It's a chicken-or-egg problem," says astronomer Edwin Bergin, Melnick's collaborator at the Harvard-Smithsonian Center for Astrophysics. "We think you need water to cool down star-formation, but we also think oxygen formed in the first stars."

## SAHARA IN SPACE

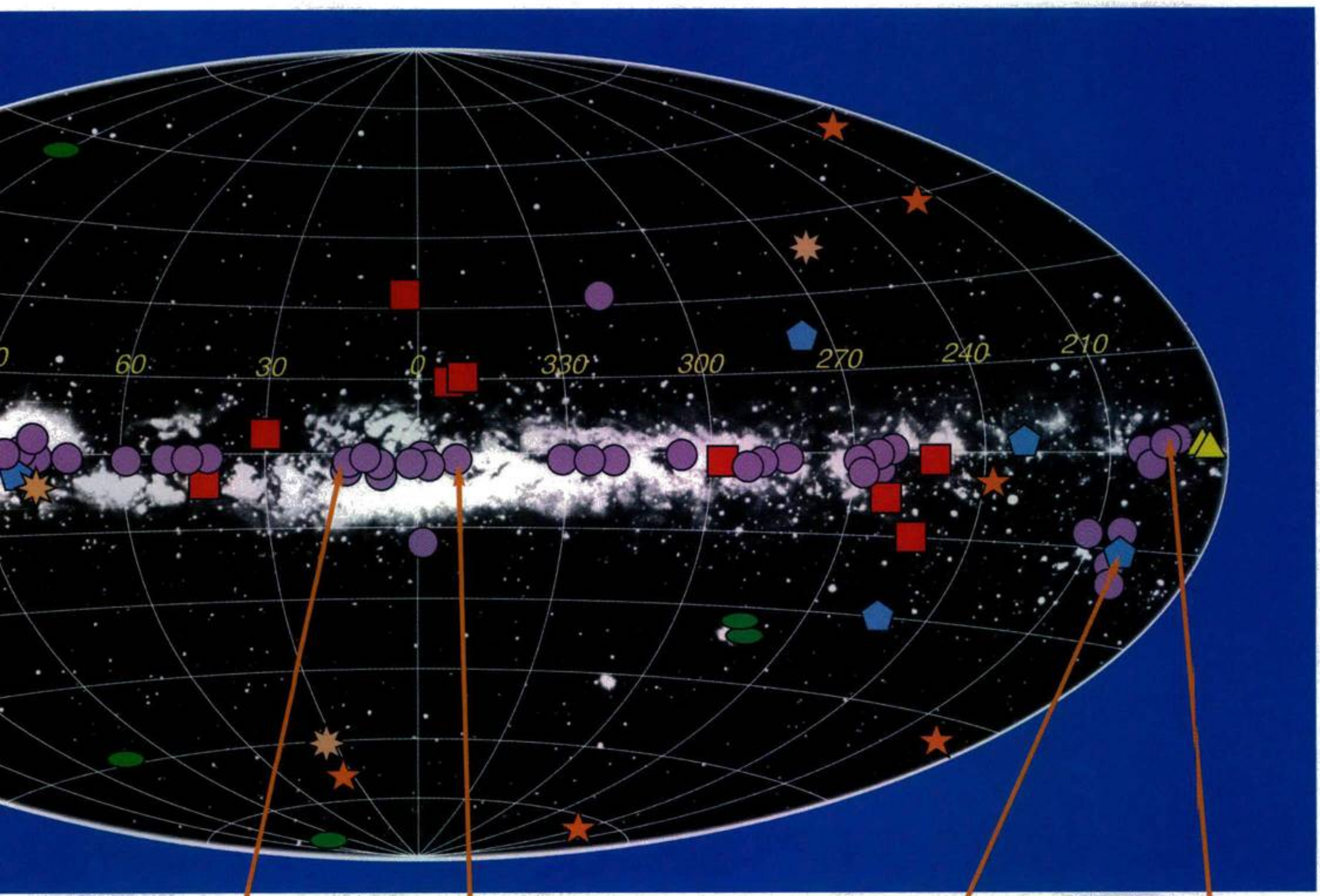
SWAS has given theorists another problem to solve: A lot of interstellar space looks unexpectedly like the Sahara Desert instead of the Everglades. Decades-old theoretical models say cold interstellar clouds should be wet, but SWAS doesn't see the moisture. "The theory predicted that these clouds would have water at one part per million," says Bergin. "SWAS is detecting only one part per billion." His colleague David Neufeld, an astronomer at Johns Hopkins University, adds wryly, "That's why we spend $70 million to test a theory."

The missing-water problem has prompted Melnick, Bergin, Neufeld, and others to provide an explanation. They believe the water isn't missing —



Martin C. Germano

**Water, water everywhere: The Submillimeter Wave Astronomy Satellite has found the signature of water molecules dispersed widely throughout the galaxy, as revealed by the above map. Squares = dark clouds; circles = giant clouds; stars = stars; triangles = supernova remnants; asterisks = planetary nebulae; ovals = galaxies; and pentagons = other types. Among the prominent emission and reflection nebulae containing water are NGC 1333 in Perseus, the Cat's Paw Nebula (NGC 6334) in Scorpius, NGC 2024 (near the Horsehead Nebula) in Orion, NGC 2264 in Monoceros, and the Omega Nebula (M17) in Sagittarius.**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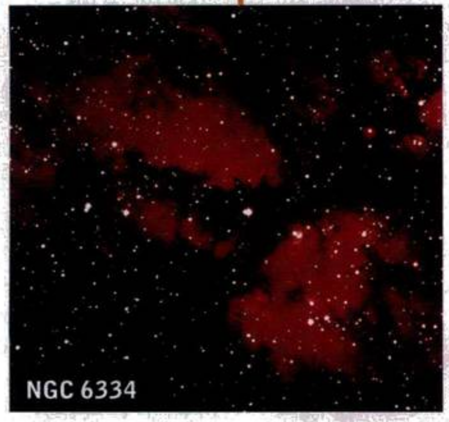
SWAS



NGC 6334

ESO

NGC 2024

Jerry Lodriguss

M17

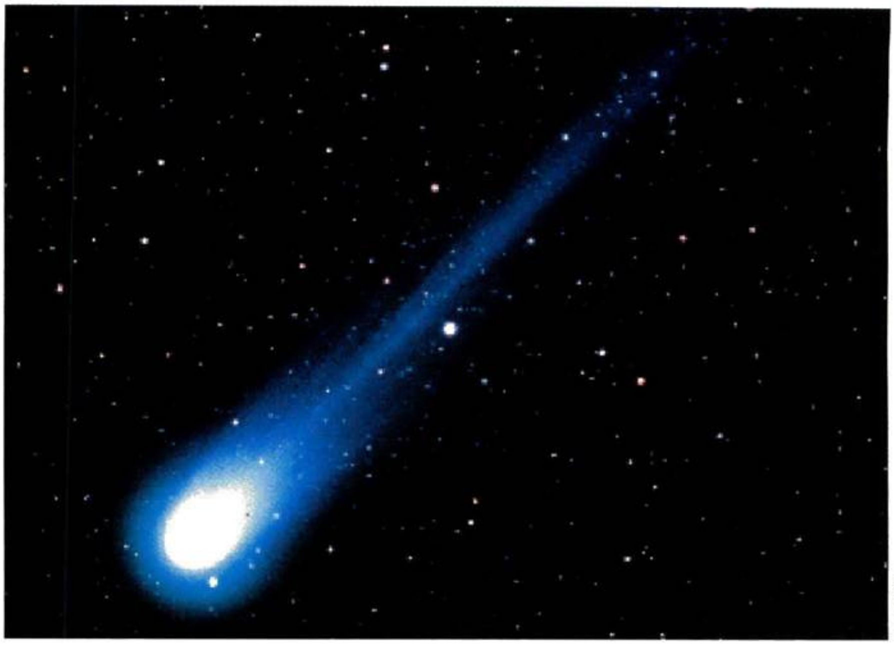
Bill and Sally Fletcher

NGC 2264

Tony and Daphne Hallas

SWAS simply can't see it because it's frozen onto the surface of tiny dust particles, and frozen water doesn't emit submillimeter-wavelength photons.

The icy-dust-grain theory is hard to confirm. Infrared telescopes observing distant stars would theoretically detect foreground clouds that contain icy dust grains. Unfortunately, such backlit clouds are rare. Nevertheless, SWAS's discoveries of unexpectedly dry clouds have elevated the icy-dust-grain theory to new prominence. That's great news for planetary scientists, says Neufeld, "because there may be a connection between interstellar icy dust grains and the glass of water you fill up at your faucet." Richard Young, the Chief of the Planetary Systems Branch at NASA's Ames Research Center, agrees. The icy-dust-grain idea fits perfectly into current thinking about how Earth got its drinking water — from icy dust grains that formed icy "planetesimals" in the vicinity of Jupiter's current orbit and then fell to Earth.



Lance Quinn

**Comets like Hyakutake contain water that may have built up Earth's oceans.**

### THE "ICE LINE" GIVETH

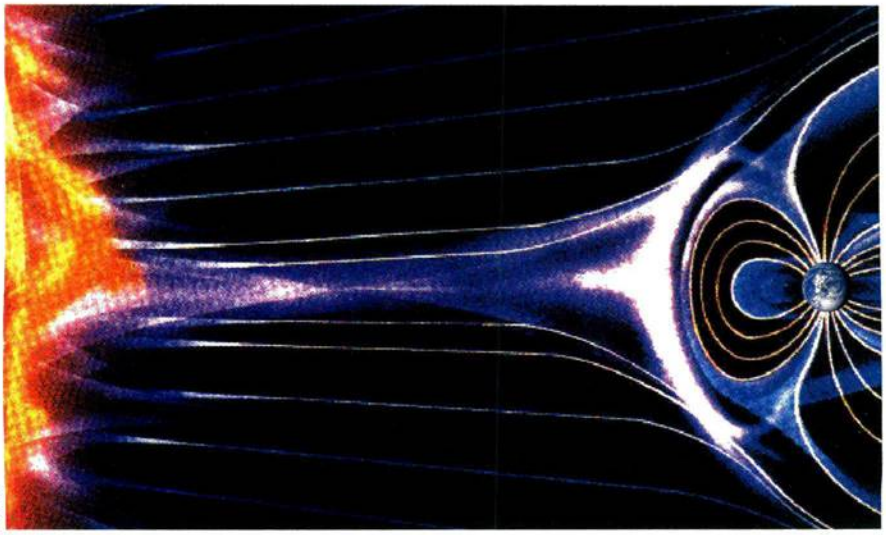
Jump back in time about 5 billion years to when our solar system was no more than a glint in the eye of an interstellar cloud of the type that SWAS sees today. Later, the center of the collapsing cloud reaches a critical density necessary for fusion of hydrogen into helium, and our sun ignites. Meanwhile, because of the slight rotation and angular momentum of the whole system, the leftovers flatten into a protoplanetary disk. Near the newborn sun, temperatures are so high that all the water is vaporized and blown out to the so-called "ice line," near the orbit of Jupiter. Here, temperatures are cold enough for icy dust balls to form.

Earth coalesced from dry, rocky material in the warmer region inside the ice line. "The Earth had to have its water delivered," says Young. Some planetary scientists argue that comets delivered our oceans, but two findings suggest that they can be responsible for no more than 10 percent of Earth's water. Detailed examinations of Comets Halley, Hale-Bopp, and Hyakutake show that all three contain nearly identical concentrations of isotopically heavy (deuterium-containing) water, and that concentration is twice as high in comets as it is on Earth. In addition, computer simulations strongly suggest that only a tiny fraction of all the solar system's comets could possibly have hit Earth. For Earth to get all of its water from comets, their combined mass would have to have been equivalent to 30 Jupiters — and planetary scientists agree that amount is much too high.

But there may have been lots of icy planetesimals.

Early in the solar system's history, such wet worlds should have formed beyond the ice line from the steady agglomeration of icy dust balls. Three of Jupiter's four largest moons — Europa, Ganymede, and Callisto — have lots of water ice. They most likely were "captured" by Jupiter's strong gravitational attraction. But their more numerous siblings were not so lucky: "They were gravitationally perturbed and started sailing in toward the sun," says Young. "A tiny number of these could have hit Earth and given us all the water we needed." The early Earth was most likely struck by at least one planet-sized body: The moon is thought to be the byproduct of such a collision. Perhaps our oceans are too.

**Earth's protective magnetosphere helps maintain liquid water on the planet.**

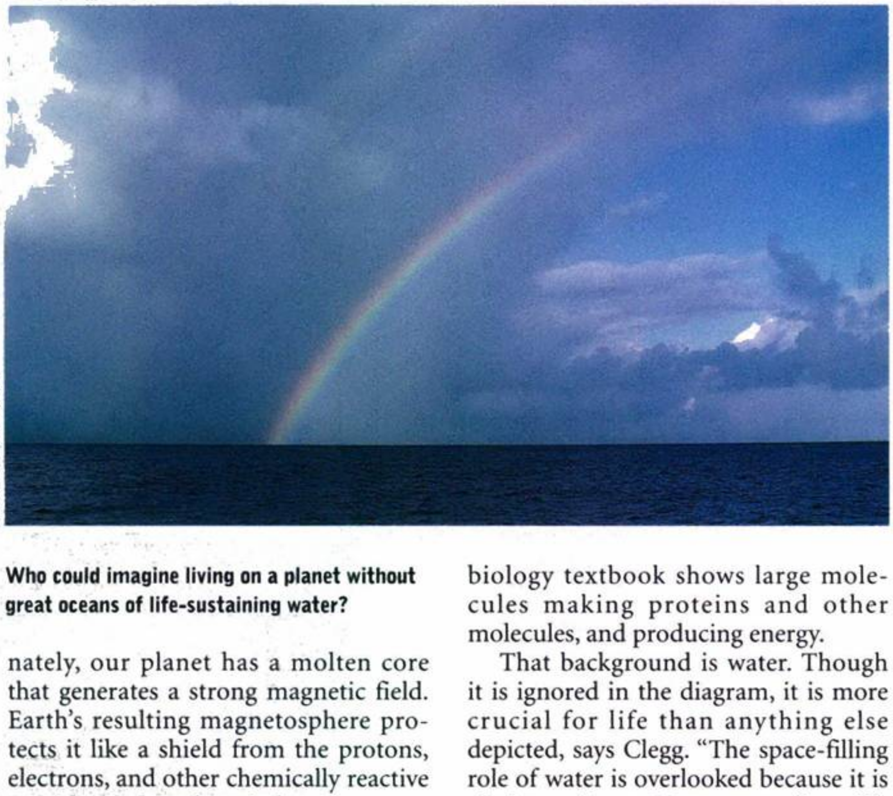


SWAS

### AN UMBRELLA KEEPS WATER IN

Young and his colleagues at NASA have developed computer models that indicate that if Earth had been larger, all of its water might have sunk to the middle and left the surface dry. Also in question is how a wet Earth could keep its surface water. Pennsylvania State geoscientist James Kasting has made estimates of the "habitability zone" and found that an Earthlike planet with a good pressurizing atmosphere can go out to the orbit of Mars and still maintain liquid water before everything freezes solid. Earth is right at the interior edge of the habitability zone with only 5 percent of the distance to the sun to spare before the oceans evaporate faster than the atmosphere can rain it back down.

The solar wind strips water from the atmospheres of all four terrestrial planets, but Kanako Seki, an astrophysicist at the Department of Earth and Planetary Sciences at the University of Tokyo in Japan, has shown that Earth's atmosphere loses matter at a rate of 6.6 pounds (3 kg) per second, or less. At that slow rate, it would take 15 trillion years to evacuate Earth's oceans. Fortunately, our planet has a molten core that generates a strong magnetic field. Earth's resulting magnetosphere protects it like a shield from the protons, electrons, and other chemically reactive particles in the solar wind.



**Who could imagine living on a planet without great oceans of life-sustaining water?**

*Astronomy*: Carol Ryback

The Mars Global Surveyor spacecraft recently found a zebra-like pattern of alternating, oppositely directed magnetic fields in regions of Mars's crust. (Plate tectonics produce similar banding patterns on Earth.) If a young Mars had a strong magnetic field, it too could have shielded a wet martian atmosphere from erosion by the solar wind. "We need to correlate the magnetic features with the age of those features," says Christopher Russell, a professor of geophysics and space physics at the University of California Los Angeles. By determining what epoch Mars was magnetized, geophysicists such as Russell can infer when oceans — and potentially life — may have existed there.

## WE'RE 80 PERCENT WATER

Clearly, Earth has been wet for most of its 4.6-billion-year history. Early in that period, water became the planet's medium of life, which has sprung up wherever water is found with remarkable vigor and diversity. It is so essential here that we equate water with life while looking out at the cosmos – to Europa, Mars, and beyond. But for all that, says James Clegg, a biologist at the University of California at Davis, water's role in life here is still underappreciated. Almost any diagram in a biology textbook shows large molecules making proteins and other molecules, and producing energy.

That background is water. Though it is ignored in the diagram, it is more crucial for life than anything else depicted, says Clegg. "The space-filling role of water is overlooked because it is obvious. About 80 percent of a cell's mass and volume is water. If it weren't for ample water, cells would be drier than beef jerky." A cell is like a pond of busy aquatic life. As a desiccated solid, a cell can't divide, process signals, or generate energy. Remove a pond's water and you have a pile of dead fish and dried lily pads.

Clegg studies creatures that can almost completely dry out — an ability called anhydrobiosis, or, more colorfully, cryptobiosis. Animals as complex as worms and insects have evolved such special ways to deal with drought. As the water evaporates from their bodies, these creatures fill their cell membranes with a sugary substance that crystallizes. Essentially, they turn into plastic. "Nothing goes on without the remarkable mother liquid," says Clegg. When rains return, the dormant animals absorb water and resume living.

We also don't know how life began. There is evidence that the organic building blocks for life came from the icy dust grains. The surfaces of these particles can catalyze the formation of many complex organic molecules, says NASA's Young. Some have even suggested that life itself began on the particles, but most scientists believe liquid water is needed for life, which only exists under pressure on a planet.

## SURVIVOR OF THE HABITABLE ZONE

We are so convinced that liquid water is necessary for life that NASA's most ambitious astronomy project yet will have the task of looking for it on rocky planets in the habitable zone around distant stars.

Called the Terrestrial Planet Finder, the flying squadron of satellites is set to launch in a decade to hunt for Earthlike planets and determine whether they have liquid water.

Life as we understand it does not exist without water. That's worth taking a moment to contemplate, and, perhaps, worship. Why are we so sure that life can only be water-based? Basically, because we can't think of any other way.

"Life requires some form of energy exchange with the environment," Stanford chemist Zare explains. "I take in energy and I do something with it. So I need a solvent to move things along. Why do you need water for life? Because otherwise you're just a rock."

Or beef jerky.

Science is a body of thought, and thought is a collection of signals moving through nerve cells that are 80 percent water. Perhaps our next-best step for solving the mysteries of water would be searching for life-forms that have thought of a better way.

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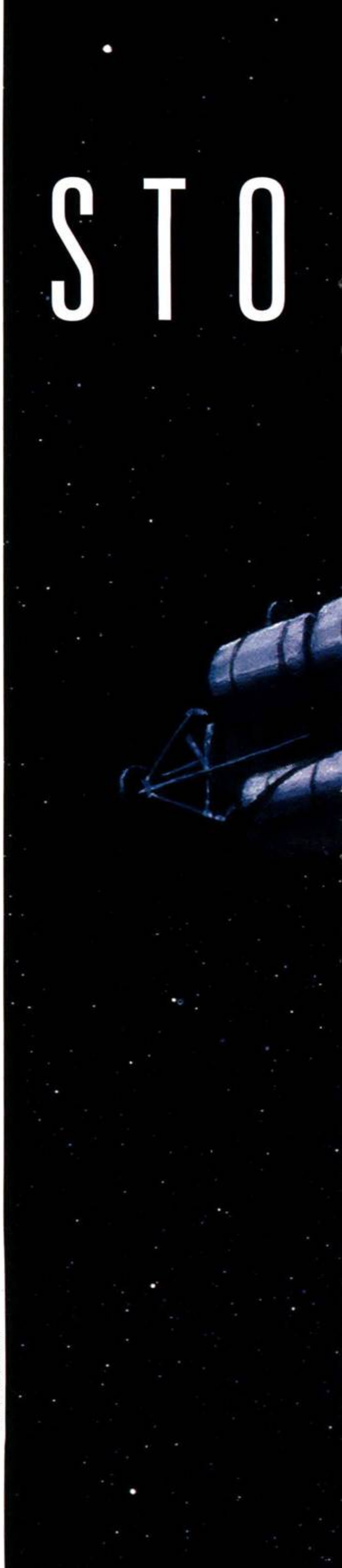
*William Speed Weed is associate producer at the American Communications Foundation in San Francisco, and a freelance science writer.*

# STEPPING STO

*As NASA contemplates a mission to the Red Planet, a near-Earth asteroid could provide an ideal trial run.*

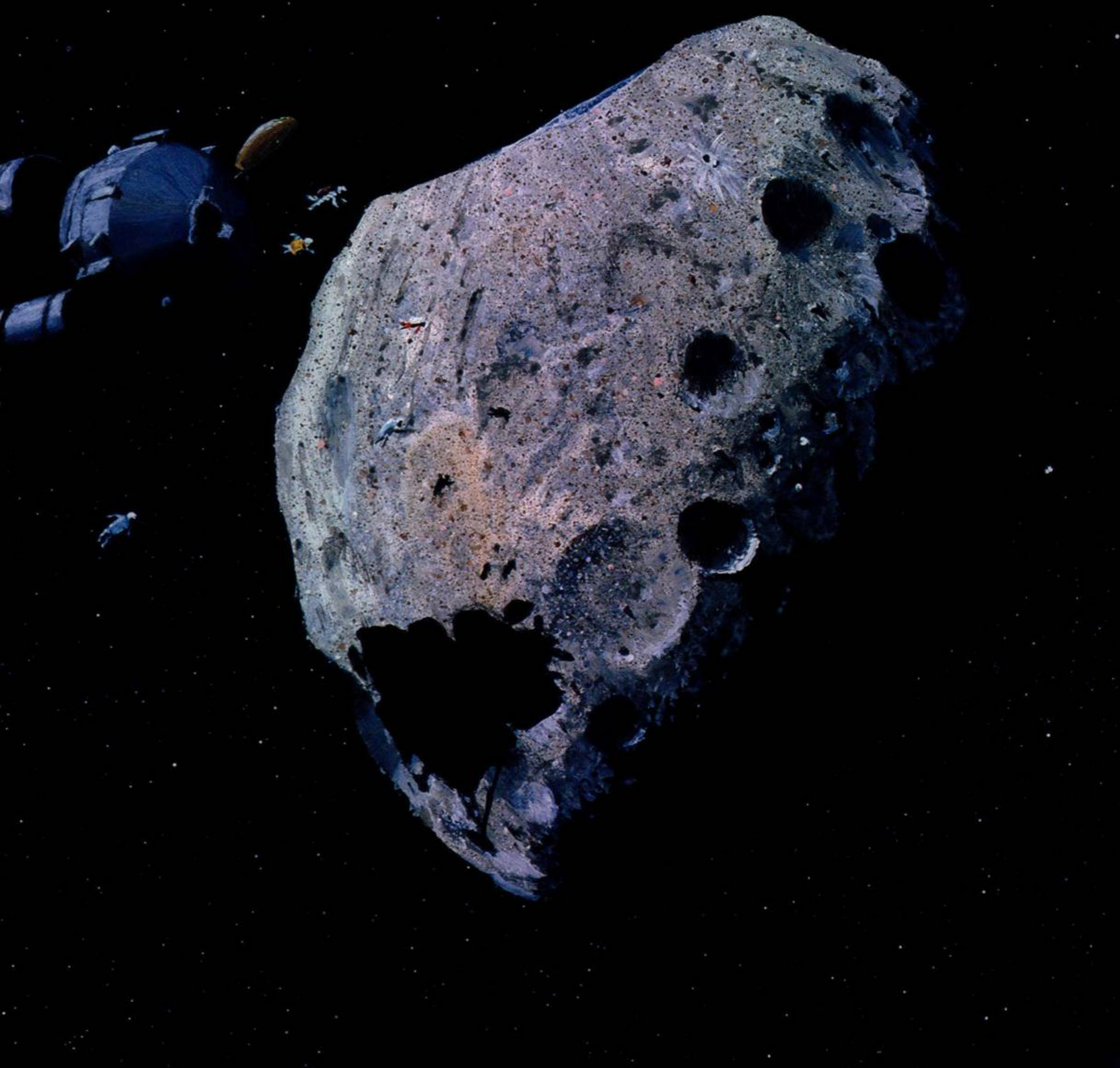
**by Daniel D. Durda**


William K. Hartmann

The arms of your spacesuit are filthy with charcoal-gray dust from the elbows down. For the last six hours you've been busily collecting rocks and soil samples from several sites across the colorless, cratered landscape spread before you. The brilliant sunlight illuminating the dark soil makes the rolling hills ahead look strangely alpine, and dashes all possibility of seeing any stars in the black sky above. That is, except for one, brilliant blue-white star halfway up the sky. It serves as a constant reminder that no matter how much the terrain around you may look like the moon, the real moon lies 10 million miles away — up there, next to that bright star that is Earth. You're not walking on the moon — you're the first person to float over the surface of a near-Earth asteroid.

The NEAR-Shoemaker spacecraft that recently rendezvoused with and then landed on the asteroid 433 Eros provided our first close-up look at one of the thousands of near-Earth asteroids (NEAs), tumbling mountains of rock that orbit the sun among the inner planets of our solar system. These diminutive denizens of near-Earth space — microworlds both scientifically and economically valuable — should prove to be equally tempting targets for future human exploration.

# NES TO MARS



The NEAs are samples of main-belt asteroids, removed from their original home between the orbits of Mars and Jupiter by gravitational perturbations from Jupiter and the other planets. They're also the parent bodies of many of the meteorites that fall on our planet, delivering small but valuable samples of fossil building blocks left over from the formation of the planets. They occasionally collide with Earth, fundamentally changing the climate, the evolution of life, and eventually, perhaps, the future of human civilization. And they could provide a vast source of mineral riches, virtual gold mines in the sky.

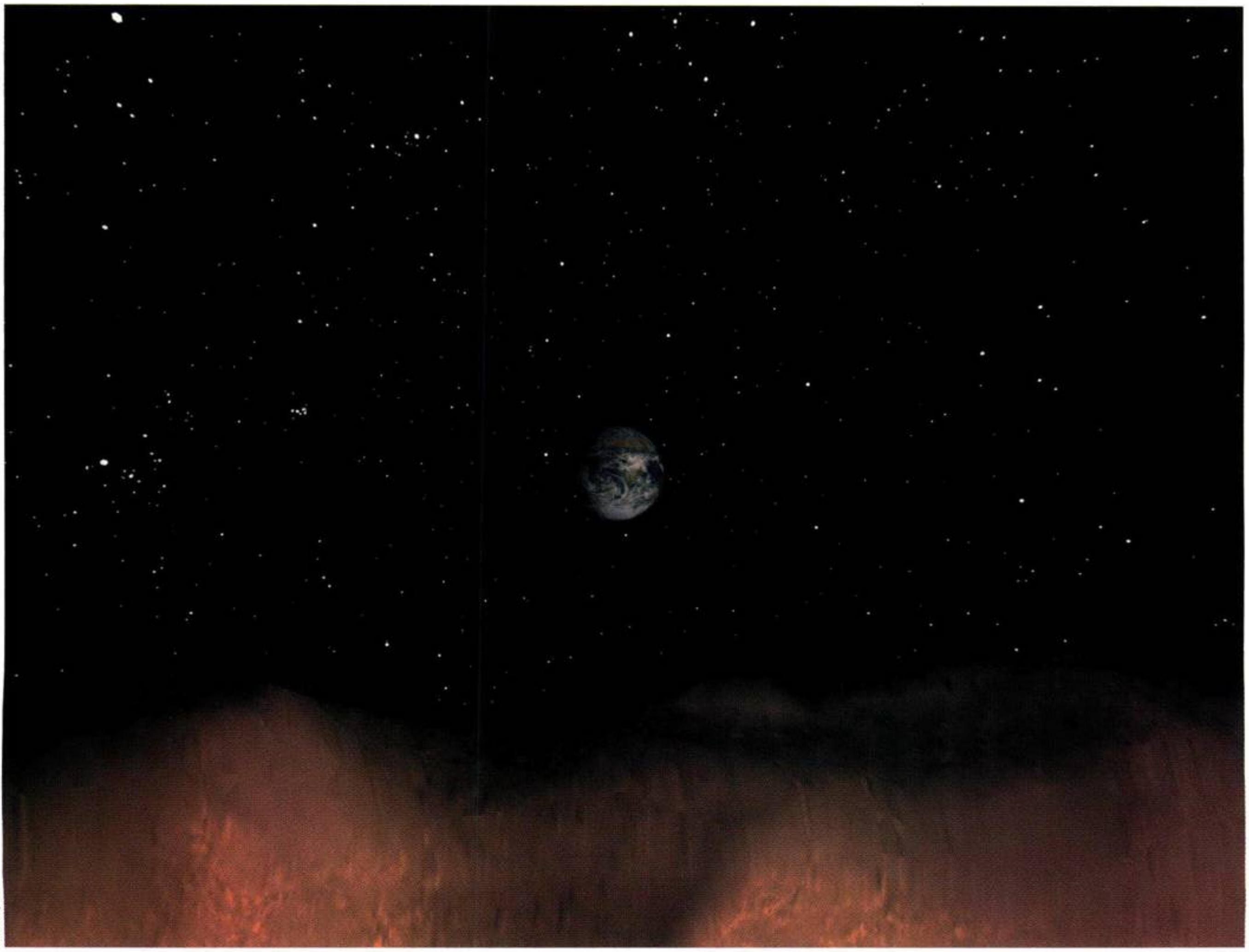
Traveling to an NEA wouldn't be as difficult as it might seem. Roughly 50 nearby NEAs larger than a third of a mile (half a kilometer) across would actually require less energy to visit than a round-trip mission to the surface of the moon. That makes these asteroids the most easily accessible bodies in the solar system. Aside from the many compelling scientific reasons, such a mission would also serve as an excellent trial run for future Mars missions with human crews. In much the same way that the Apollo 8 mission around the moon daringly paved the way for the moon landings that soon followed, we could use the NEAs as stepping stones to Mars, testing the capabilities of the hardware, probing the limits of mission design, and inspiring countless people with an exciting preview of a mission to the Red Planet.

Without the need for a costly lunar module to land on the moon's surface, Apollo 8 cost about three quarters as much as Apollo 11, and just one third as much as the far more ambitious Apollo 17. Current estimates place the cost of landing humans on Mars at about $55 billion. Although NASA has no plans yet to send astronauts to an NEA, the Apollo program's history suggests that such a Mars rehearsal mission might run $15 billion to $20 billion. That cost could be recouped by reusing the NEA mission vehicle on a future Mars mission.

## GETTING THERE

What would it be like to travel to and explore a near-Earth asteroid? Not surprisingly, any NEA chosen as a target for early human exploration would likely have an orbit closely resembling Earth's. Such a target would reduce the total energy needed to reach the asteroid, rendezvous, and return home. It would also substantially reduce the time needed to complete the round-trip, cutting costs and lessening the risks to the crew of extended exposure to radiation and zero gravity.

As a shorter dress-rehearsal for a Mars mission, the astronaut crew would depart low-Earth orbit in essentially the same transfer vehicle that would be used for the first journey to the Red Planet. Just as Apollo 8 rounded the moon without a lunar module, however, the NEA crew would not need the expensive Mars habit and



**Our planet would appear as more than a dot to astronauts on an NEA. This computer-created image shows Earth from the asteroid Toutatis.**

NASA/JPL

Johns Hopkins University and NASA

**The first robotic exploration of a near-Earth asteroid came this past year, when NEAR-Shoemaker went into orbit around Eros.**

cargo landers for its mission. Although a mission to a nearby NEA would demand only a fraction of the energy required to reach Mars, it might still begin with the full complement of fuel needed for an actual Mars mission. With crew safety a top priority, NASA would like to keep the option of being able to abort the mission at any time and rapidly return the crew to Earth in case a system fails or a medical emergency arises.

Mission planners would have plenty of NEAs to consider as targets. Although an individual object might make a close pass to Earth only once every several years, remember that some 50 NEAs can be reached using less energy than that needed to travel to the moon's surface. That leaves a dozen or so opportunities each year to launch a mission to an attractive NEA.

Depending on the particular target, it could take anywhere from a few months to a year or more to travel from low-Earth orbit to an NEA. The whole trip there and back might take several months or stretch to more than two years, much like an actual mission to Mars. Despite the travel time, NEA crews might never have to stray very far from the comforting blue glow of our home planet. The path from low-Earth orbit to a good NEA target would likely take human explorers no farther than about 0.15 astronomical unit from Earth at any point during the course of a typical NEA mission. That's only 13.9 million miles (22.4 million kilometers), or about 58 times as far from Earth as the moon.

Even at its farthest point during the flight, Earth would appear no smaller than about 2 arcminutes across through the spacecraft's windows, just big enough to resolve with the naked eye as a brilliant blue-white disk. On the first such deep space venture, astronauts would no doubt find that a reassuring sight. The NEA crew would also be able to carry on something resembling a normal conversation with mission control. Unlike a mission to Mars, where the round-trip travel time for radio communications could stretch up to 40 minutes, an NEA crew would face at most a 2.5-minute time lag.

Upon arriving at the asteroid, the spacecraft would initially enter a high orbit from which the astronauts would conduct a precise survey of the asteroid's shape and gravitational field. (Although Earth-based radar observations and a cheap precursor robotic mission would almost certainly have provided important preliminary data on the asteroid's shape and mass.) As the crew lowers the spacecraft's orbit closer to the asteroid, the astronauts would study the detailed morphology of the rocky surface, map the distribution of minerals, and scout out safe but scientifically interesting landing sites.

Once this preliminary reconnaissance has been completed, the spacecraft would be parked in a stable orbit and serve as a base of operations for several excursions to the asteroid's surface over a period of as long as a few

## MINING THE SKY

Although the first human missions to near-Earth asteroids will likely concentrate on scientific studies, the enormous resource potential will make NEAs valuable destinations for continuing missions. NEAs are a compositionally diverse population of rocky and metallic bodies offering a mineralogical smorgasbord far richer and easier to reach than materials on the lunar surface. Almost all NEAs have a hundred times more metal not bound up in rocky minerals than do moon rocks.

Nearly pure flakes of nickel-iron alloys could be collected by simply dragging a magnetic rake through the soil covering a typical chondritic asteroid. Byproducts from refining these alloys would include precious and strategic metals such as platinum, palladium, chromium, and gold. Abundant sulfur would be a valuable non-metal resource, as would oxides of elements such as calcium and aluminum, which could be used in making heat shields. Even unprocessed soil could be used for shielding to protect astronauts on longer missions from cosmic rays and solar flares. Carbonaceous asteroids would be a rich source of water and organic compounds for life-support fluids and rocket propellants.

As the population of our small planet continues to grow and pressures to exploit ever-dwindling resources on Earth increase, it seems only natural to begin to look elsewhere for some of the materials we will need. We may not have to search any further than the asteroids in our backyard. — *D. D.*

weeks. Personal transportation and maneuvering units, similar to the Manned Maneuvering Units once used by Space Shuttle astronauts, could be used by the surface crew to travel back and forth between the orbiting vehicle and the surface.

## ON THE ROCKS

The surface of a small asteroid will present astronauts with a geologic environment quite different from the moon or Mars. Although a myriad of craters of various sizes will pepper the asteroid's dusty, rock-strewn soil, there ends any great similarity to the lunar surface experienced by Apollo astronauts. The topography in some places might be extreme. NEAR-Shoemaker's images of Eros and radar observations of several other small NEAs reveal a veritable zoo of irregular shapes. Large ejecta blocks, undulating plains between overlapping large craters, and ridges and facets that define the overall shape of the asteroid could make for a wildly varying terrain with locally very steep slopes.

On worlds the size of small towns, the horizon never lies far away — the vista over the other side of the next hill might well fall away beneath you to encompass the whole other side of the asteroid. Astronauts will also have to deal with rapidly changing lighting conditions. The rotation periods of many small NEAs are only a couple of hours, much shorter than the astronauts' space suits should allow them to explore. Surface crews may well witness several sunrises and sunsets during their excursions as they investigate their tumbling mountain.

The extremely low surface gravity and rapid rotation of a typical NEA will provide interesting challenges to those trying to move around on the surface. A half-mile-wide NEA has a surface gravity only 1⁄28,000 that of Earth. Even a fully suited astronaut equipped for exacting field studies would weigh barely as much as a handful of paperclips. An object "dropped" from an astronaut's outstretched hand would take some 75 seconds to settle to the surface. Anyone could easily toss a rock into orbit or off the asteroid altogether. And forget about walking or driving a rover across the undulating landscape.

Astronauts would even have to forgo the simple, arcing "hops" they might use on round, slowly rotating worlds. Instead, the flight path of an astronaut traveling from one point to another on an NEA appears convoluted, and becomes more so the greater the distance covered. Tugged and pulled by the asteroid's weak but complex gravity field as the lumpy landscape rotates beneath them, astronauts would appear to someone on the surface to be making complicated and twisted loop-the-loop trajectories in the sky above.

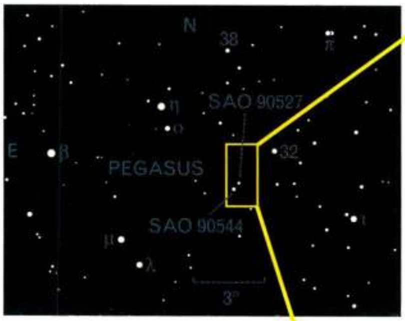
In some ways the near-weightless environment could assist the astronauts. They would be able to reach just about any point on an asteroid from their orbiting mother ship and their mobility on the surface would be enhanced by being able to float over rough terrain and high obstacles.

The surface environment, however, would pose other daunting challenges. Each personal maneuvering unit would need advanced transportation and

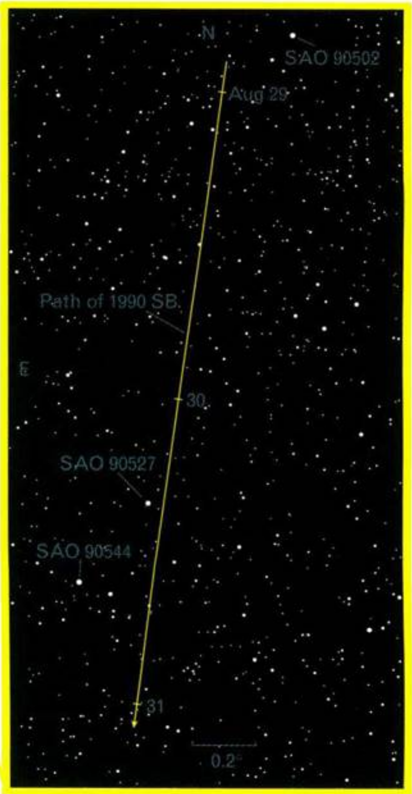
## HUNTING FOR A NEAR-EARTH ASTEROID

Tiny objects with dark surfaces, near-Earth asteroids don't dominate the night sky. No surprise there. What may come as a surprise is that occasionally you can spot one with a modest-sized backyard telescope. All you need is a clear night, a little patience, and the knowledge of where to look.

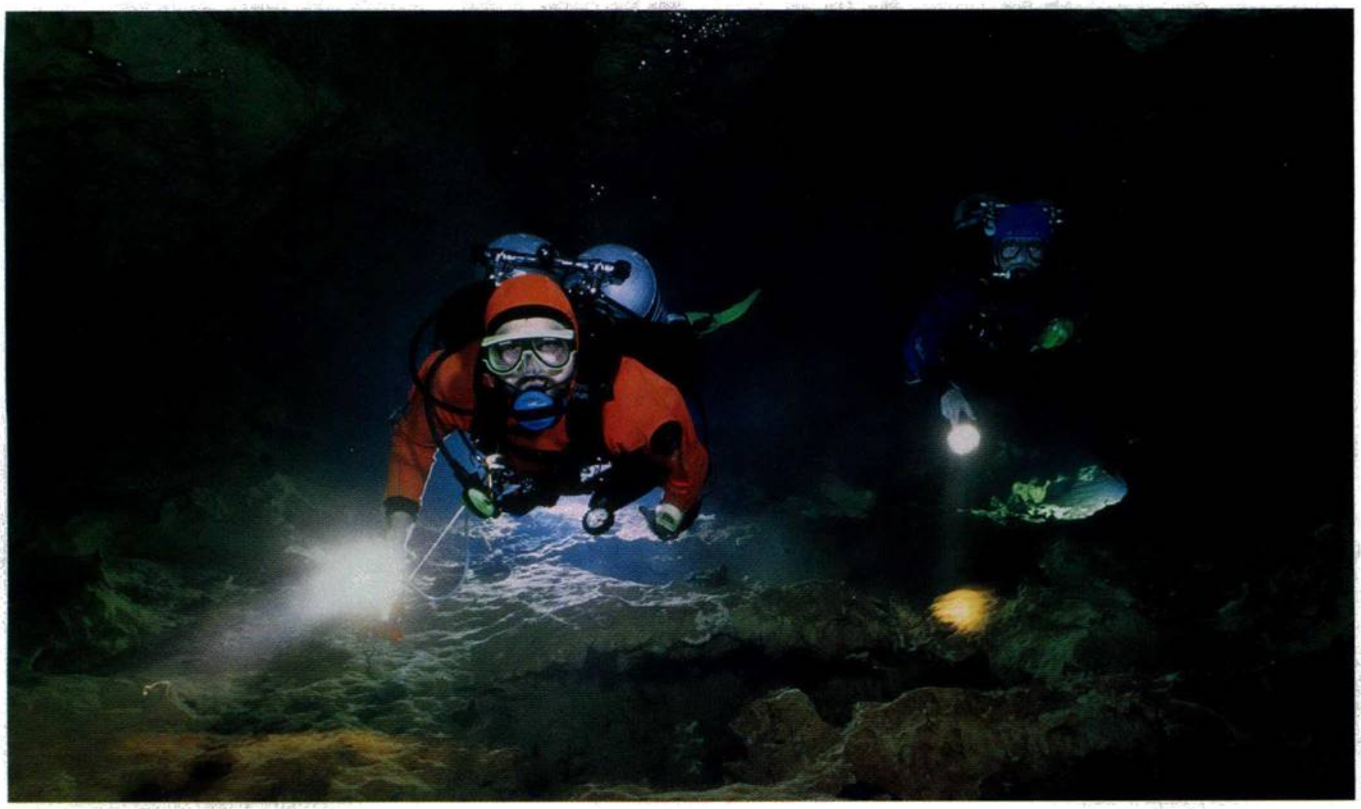
The brightest near-Earth asteroid to appear in our sky during the next couple of months goes by the prosaic name of 1990SB. The 5,587th asteroid to have its orbit determined precisely, 1990SB dips within 23 million miles of Earth in late August and early September. That's close enough that the 8-mile-diameter object will glow at magnitude 13.3, some 50 percent brighter than Pluto at its best and well within the range of an 8-inch telescope. Even better, it lies in a relatively uncluttered field in the constellation Pegasus the Flying Horse, which climbs fairly high into the sky for Northern Hemisphere observers in late summer.



To track down the asteroid, first locate the Great Square of Pegasus, a distinctive asterism that's located high in the southeast during late evening. Use the 3rd-magnitude star Eta (η) Pegasi, located just northwest of the Great Square, as your starting point. Follow the pattern of stars from Eta to the location of the asteroid depicted on the detailed map, which shows positions at 11 P.M. EDT. You should be able to pinpoint it with just the map, but if you aren't sure which point of light it is, wait a few hours. The movement of 1990SB will be a dead giveaway. — *Richard Talcott*



*Astronomy*: Kellie Jaeger



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**Astronauts exploring the surface of an NEA would have more in common with cave divers on Earth than with the Apollo moonwalkers.**

navigation systems to reliably move an astronaut from place to place. The units would consume plenty of propellant, but the astronauts would have to exercise the utmost care when firing the gas thrusters near the asteroid's surface. Any dust stirred up would settle very slowly, obscuring visibility and making a mess of both equipment and scientific samples.

Once on the surface, the explorers will survey and photograph the local environment and collect rock samples. Instead of bounding about the landscape as Apollo astronauts did on the moon, a crew experiencing the milli-gravity of an NEA would float over the surface, tethered to the asteroid and work platforms like astronauts repairing a satellite in Earth orbit. Asteroid surface teams might have more in common with cave divers than moonwalkers; the astronauts could enjoy all the benefits of three-dimensional motion but would have to move with care and finesse, perhaps at times using only a fingertip to move or steady themselves.

The rock and soil samples carefully collected by the astronauts, along with astute observations of the geologic settings in which they were gathered, would help answer a myriad of important scientific questions. Which of the various meteorite types — ordinary chondrites, irons, carbonaceous chondrites, and others — come from the different compositional classes of asteroids? What process "space weathers" the surface soils of asteroids, and is it like the process that darkens and reddens lunar soils over time? Are the rocks collected from the "bedrock" of the asteroid different from those culled from the impact-processed soil?

Detailed studies from orbit, coupled with seismic experiments on the surface, should tell planetary scientists about the internal structure of the asteroid itself. Is it a monolithic mountain of rock, or are there signs expressed in the landscape indicating that its interior has been shattered by large impacts? Answers to some of these questions could have practical implications for protecting our planet from the threat of future impacts by similar small asteroids.

When the field work has been completed at one scientific site, the exploration team would pull up stakes and move to another site. After the last soil sample had been scooped up, when no more hand-picked meteorites would fit in the sample bags, the time would come to wrap up the mission's surface exploration phase and begin the trip home.

The crew would depart the asteroid and return to Earth using the same trajectories and recovery techniques designed for Mars missions. Although a typical return trajectory would be a near mirror image of the journey to the asteroid, the trip back might be hastened by judicious target selection, orbit design, and perhaps by burning a bit of the extra fuel that was carried along as a safety margin on the outbound leg of the trip.

Anywhere from a few to several months after leaving the asteroid, with our home planet once again looming large in the sky, the astronauts would enter the Earth return capsule and prepare for a fiery entry through the atmosphere. Although splash down would signal the end of this mission, it could herald the start of a more ambitious one. After all, before the boots of astronauts are stained red by martian sands, human crews learning to explore beyond both Earth's orbit and the moon may stir the black dust of a near-Earth asteroid.

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*Planetary scientist Daniel D. Durda studies asteroids at the Southwest Research Institute in Boulder, Colorado. He is also an accomplished pilot, cave diver, and space artist.*

# ORION
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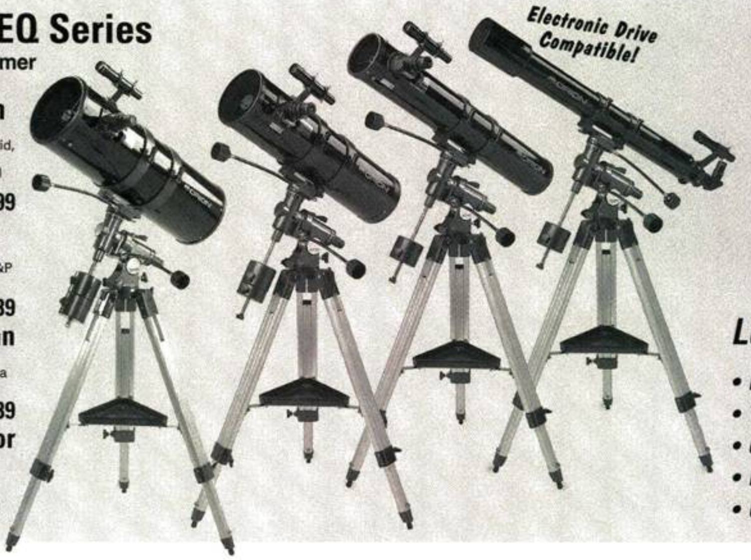
## TELESCOPES

## Orion SkyView™ Deluxe EQ Series
**Telescopes for *Today's* Amateur Astronomer**

*Electronic Drive Compatible!*



### SkyView™ Deluxe 8 EQ Newtonian
A deep-sky lover's delight! Big, diffraction-limited 200mm parabolic primary mirror of 800mm focal length (f/4) delivers vivid, wide-field views of nebulas, clusters, and galaxies. Gathers 73% more light than a 6" scope, yet is nicely portable. Enameled steel tube and aluminum R&P focuser (1.25").

Was $649 **Now $599**

### SkyView™ Deluxe 6 EQ Newtonian
Outstanding for deep-sky and planetary/lunar study. Features a precision 6"-diameter **parabolic** primary mirror and aluminum R&P focuser. Enameled steel optical tube. Focal length 750mm (f/5).

Was $499 **Now $439**

### SkyView™ Deluxe 4.5 EQ Newtonian
An exquisite combination of form, function, and affordability for the serious beginning astronomer. The rolled steel optical tube houses a precision-polished 4.5" primary mirror of 920mm focal length (f/8).

Was $379 **Now $339**

### SkyView™ Deluxe 90mm EQ Refractor
Exceptionally crisp views of the Moon, planets, and beyond! Multi-coated 90mm achromatic objective lens of 1000mm focal length (f/11.1). Seamless aluminum optical tube.

**$399**

*Super* **Sale!** *on selected items*

### *Look What's Included*
- *New heavy-duty EQ mount*
- *TWO 1.25" Plössl eyepieces*
- *6x30 achromatic finder scope*
- *Moon filter (1.25")*
- *Gold-anodized aluminum tripod*

### Observer 60mm Observer™ Altaz Refractor

This value-priced Observer with altazimuth mount is especially popular with younger astronomy enthusiasts. Includes 5x finder scope, 90° mirror diagonal, 25mm (28x) Kellner eyepiece (1.25"), and altitude fine-control arm, Aluminum tripod. Focal length 700mm (f/11.7)

Reg. Price $89.95 SALE **$79.95**

### Orion ShortTube™ 4.5 EQ Reflector

This is a complete telescope package, inclduing 5x finder scope, rack and pinion focuser, two fully coated 1.25" Kellner eyepieces: a low-power 25mm (40x) and a high-power 10mm (100x), plus hardwood tripod with accessory tray. It's a terrific starter scope that's delightfully short on bulk!

**$199**

### Orion ShortTube™ 90mm EQ Refractor

The most portable 90mm refractor ever. Less than 20" long, but packs 27% more light-gathering capability than an 80mm refractor. Its 500mm focal length (f/5.5) provides gorgeous wide-field views. Includes 6x30 finder scope, 26mm (19x) Sirius Plössl eyepiece (1.25"), prism star-diagonal, and beefy EQ-2 mount

Reg. Price $439 SALE **$399**

## Orion SkyQuest™ XT Dobsonian Telescopes
***Big Aperture, Superior Performance, Point-and-View Simplicity***

For a fraction of the cost of a little "go to" scope, you can own a telescope with serious aperture. See more of the universe—for less—with an award-winning SkyQuest XT metal-tube Dobsonian. It'll keep you up nights.

***ENAMELED STEEL TUBE, NOT CARDBOARD!***

**SkyQuest XT4.5**
Just the right size for younger stargazers, and incredibly easy to master! Adults will love it too, for its portability and crisp optical performance.
*Steel tube, 114mm mirror (f.l. 910mm, f/8), 1.25" R&P focuser, 6x30 achromatic finder scope, 25mm (36x) and 9mm (110x) Plössl eyepieces (1.25"), 5" flanged altitude hubs, CorrecTension Friction Optimization, built-in handle, dust cap. Weight: tube 9 lbs., base 8-1/2 lbs.*

**$229**

**SkyQuest XT6**
The overachieving XT6 will show Jupiter's Red Spot, Saturn's Cassini Division, hundreds of clusters and nebulas, and galaxies tens of millions of light-years distant. Nicely portable and very affordable!
*Steel tube, 152mm parabolic mirror (f.l. 1200mm, f/8), 1.25" aluminum R&P focuser, 6x30 achromatic finder scope, 25mm (48x) and 9mm (133x) Plössl eyepieces (1.25"), Moon filter, eyepiece rack, 5" flanged altitude hubs, CorrecTension Friction Optimization, dust cap. Weight: tube 13 lbs., base 24 lbs.*

**$369**

**SkyQuest XT8**
The XT8's prodigious performance on both solar system and deep-sky denizens have made it the telescope of choice for thousands of astronomers, from beginners to die-hard hobbyists.
*Steel tube, 200mm parabolic mirror (f.l. 1200mm, f/6), 1.25" aluminum R&P focuser, 6x30 achromatic finder scope, 25mm (48x) and 9mm (133x) Plössl eyepieces (1.25"), Moon filter, eyepiece rack, 5" flanged altitude hubs, CorrecTension Friction Optimization, dust cap. Weight: tube 19 lbs., base 23 lbs.*

**$499**

**SkyQuest XT10**
Gulping in over 50% more light than an 8" scope, the XT10 reaches far deeper into space. The sheer number of objects visible in this scope is staggering, and its resolving power brings out detail that will keep you entranced for years.
*Steel tube, 250mm parabolic mirror (f.l. 1255mm, f/5), 2" aluminum R&P focuser, big 8x50 achromatic finder scope, 25mm (50x) and 9mm (139x) Plössl eyepieces (1.25"), Moon filter, eyepiece rack, 5" flanged altitude hubs, CorrecTension Friction Optimization, dust cap. Weight: tube 35 lbs., base 23 lbs.*

**$649**

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# EYEPIECES & ACCESSORIES

### Sirius™ Plössl Eyepieces

You could pay twice the price for other brands of Plössl eyepieces, but why? Sirius Plössls are top-quality, 50° apparent-field (43° 40mm) eyepieces that yield extremely sharp images of impressively high contrast. Ideal for all types of telescopes. Fully-coated optics, rubber eyeguards.

**1.25"**

| | |
|---|---|
| 6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm | $49.95 each |
| 32mm, 40mm | $59.95 each |

## Save Big on Sirius Sets!

### *Need More Than One?*

Save on these practical Sirius Plössl sets. (You save on shipping, too!) 1.25" barrel diameter only.

### Sirius Plössl Starter Set

And ideal "upgrade" set to replace lower-quality eyepieces, it includes three must-have focal lengths for low-, medium-, and high-power viewing: 26mm, 17mm, and 10mm.

Reg. $149 Set Price **$119**

### Sirius Plössl Expansion Set

If you already have the Starter Set, or the 25mm and 10mm eyepieces included with many telescopes, this set provides three complementary focal lengths for medium and high magnifications: 20mm, 12.5mm, 7.5mm.

Reg. $149 Set Price **$119**

### Sirius Plössl Power Pair

For planetary and lunar viewing especially, these 12.5mm and 7.5mm high-power oculars will have you discovering new detail. Even if you already use a 9mm or 10mm eyepiece, get this pair to add more magnification options.

Reg. $100 Set Price **$79.90**

### Explorer II™ Eyepieces

The cost of accessories for your telescope can really add up. Now you don't need to spend a fortune for good quality oculars. Our Explorer II models are attractively priced for even limited budgets. Their 3 and 4 element glass lens configurations provide a 50° apparent field of view. They're fully coated with anti-reflection material to maximize transmission of incoming light and improve contrast. The anodized aluminum barrels are precisely machined and internally blackened to prevent stray light reflections. They're also threaded for filters. Available in 25mm, 17mm, 13mm, 10mm, and 6mm focal lengths.

$27.95 each

### Orion Lanthanum Eyepieces

Our rare-earth lanthanum eyepieces have new chrome exteriors but the same superior image correction and generous 20mm eye relief of the previous models. Ideal for eyeglass wearers! Fully multi-coated optics with six to eight lens elements. Apparent field 50° (7.5-25mm), 45° (2.3mm-5.2mm). Pop-down rubber eyecups. Made in Japan. 1.25" barrels.

| | |
|---|---|
| 3.8mm, 5.2mm, 7.5mm, 9.5mm, 10.5mm, 12.5mm, 14mm | $109 each |
| 2.3mm, 18mm, 21mm, 25mm | $119 each |

### Orion Solar Filters

Catch this year's intense sunspot activity with a safe, full-aperture glass solar filter for your telescope. Sizes to fit many telescopes.

From $54.95

### Orion LaserMate™ Collimator

Align your Newtonian's optics to get the best possible images. This compact laser collimator removes the guesswork, making the procedure quick and extremely precise. Just 3-1/3" long!

Only $69.95

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AVOID DIRECT EYE EXPOSURE
LASER DIODE
5mW PWR. OUTPUT, WAVELENGTH 630-680nm
CLASS IIIA LASER PRODUCT

### Aluminum Accessory Cases

Rugged and classy looking. Pre-cut, cubed foam inside to fit your specific accessories. Ample room for giant eyepieces, camera body, lots of stuff!

| | |
|---|---|
| Medium Case | $29.95 |
| Large Case | $44.95 |

### Orion EZ Finder™

ORION EZ Finder

Illuminated "red dot" in nonmagnified 9° field of view shows right where telescope is pointed. Adjustable brightness. Attaches to any telescope.

$39.95

### Planetary Filter Set

These vat-dyed glass color filters bring out fascinating surface details on the planets and Moon.

Set of four $44.95

### Shorty-Plus™ 3-Element 2x Barlow

Just 2-3/4" long, Shorty-Plus has air-spaced, three-element apochromatic design and fully multi-coated optics for highest quality power-boosting performance.

$64.95

### Padded Scope Cases

Protect your investment with a padded, polyester/nylon case. Strap handles for easy carrying. Many sizes.

From $29.95

# BINOCULARS

TRIPOD
L-ADAPTER
INCLUDED!

### Little Giant™ II 70mm Binocular

More compact than the original Little Giants. Big 70mm objectives reveal a plethora of nebulous clouds and stellar clusterings. Great for twilight and daytime use too. Sharp, fully multi-coated optics with BAK-4 prisms. Large, knurled center focus wheel. Classic black coarse-grain finish. Tripod L-adapter, case, and deluxe wide neck strap included. Made in Japan.

| | |
|---|---|
| **11x70** 4.5° field | $259 |
| **15x70** 4.0° field | $259 |
| **20x70** 3.0° field | $259 |

### Intrepid™ 10x60 LE Bino

Affordable big binocular with 60mm aperture. Long 20mm eye relief, 5.3° field of view and fully coated optics. Equipped with center focus wheel and rubber armor. Carrying case and neck strap included.

$119

New!
EXTENDABLE
DEW/GLARE SHIELDS!

### MegaView™ 80mm Binoculars

Premium giant binoculars with high-power optics and cross-reinforced aluminum body and sliding tripod mounting post for optimum balance. Fully multi-coated 80mm lenses with BAK-4 prisms. Long eye relief.

| | | |
|---|---|---|
| **15x80** | 3.5° field | $479 |
| **20x80 WA** | 3.5° field | $489 |
| **30x80 WA** | 2.3° field | $499 |

---

### Scenix™ 50mm

Newly upgraded with BAK-4 prisms for improved images. Multi-coated optics. Metal housing, not plastic. Tripod adaptable.

| | |
|---|---|
| **7x50** 7.1° field | $77.50 |
| **10x50 WA** 7.0° field | $77.50 |
| **12x50 WA** 6.0° field | $77.50 |

LONG EYE RELIEF!

### UltraView™ 50mm

Extra-long 22mm eye relief makes these superb for eyeglass wearers! Fully multi-coated optics, BAK-4 prisms. New twist-lock eyecups. Tripod adaptable.

| | |
|---|---|
| **7x50** 6.5° field | $159 |
| **10x50 WA** 6.5° field | $159 |

FULLY
MULTI-COATED
OPTICS

### Vista™ 50mm

Featherlight High-Performance Binoculars. High-index BAK-4 prisms and fully multi-coated optics for high-fidelity images. Soft leatherette covering. Tripod adaptable.

| | |
|---|---|
| **7x50** 6.0° field | $199 |
| **10x50 WA** 5.3° field | $199 |

LONG EYE RELIEF!

### Mini Giant™ Binos

Compact astro binocs that show you the light! Fully multi-coated optics, BAK-4 prisms. Long eye relief (8x56: 18mm, 9x63: 26mm). Easily hand-holdable, but also tripod adaptable.

| | |
|---|---|
| **8x56** 5.8° field | $159 |
| **9x63** 5.0° field | $189 |

TRIPOD
L-ADAPTER
INCLUDED!

### Giant 80mm

Stunning resolution of clusters, nebulas, and lunar surface detail. Fully multi-coated optics with BAK-4 prisms. Objective bridge for added rigidity. Center focus. Tripod L-adapter included. Long 15mm-16mm eye relief.

| | |
|---|---|
| **11x80** 4.5° field | $388 |
| **16x80** 3.5° field | $388 |
| **20x80** 3.5° field | $388 |

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# sky Show

## august

Mars commands the evening sky as shooting stars reach a maximum.

by Martin Ratcliffe and Alister Ling

A bright Perseid meteor streaks across Cygnus and Lyra on August 12, 1985. Dale Lightfoot

▶ Like a stationary lighthouse beacon alerting travelers of its presence, Mars blazes low in the hazy summer evening sky. Time is running out for observers because the Red Planet is shrinking as Earth pulls ahead in its faster orbit. To see surface features, Mars needs to be close, and therefore big, while Earth's atmosphere should be as steady as possible. Mars has already shed 20 percent of its apparent size since its peak diameter in June, and it will lose another 20 percent this month.

The bright star Antares, the namesake rival of the Red Planet, seemed to anchor Mars last month. But as Earth sails ahead on its faster orbit, Mars appears to veer left and fade rapidly. It looks as if someone were adjusting Mars's dimmer switch each week.

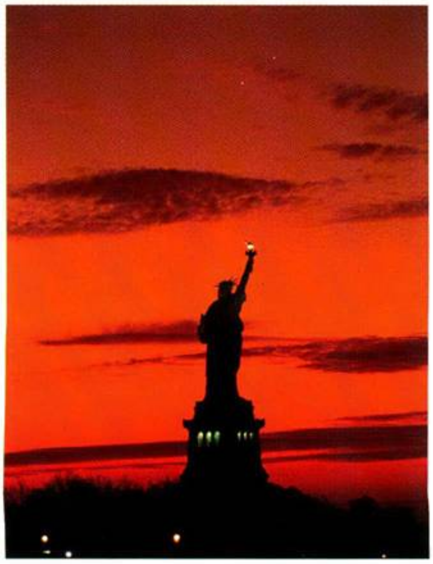
Appearing on stage now in the morning sky, Jupiter and Venus show off in a grand conjunction. During the first week of August, the brilliant Venus sinks downward to meet the rising gem Jupiter. They lie closest on the 5th and 6th, only two apparent moonwidths apart. The crescent moon cruises past on the 15th and 16th. The greatest challenge is to wake up at 4 A.M. to see it. You can also find them in daylight by taking proper precautions and offsetting the right amount from the sun.

Be sure to mark August 15th on your calendar. The crescent moon will occult, or cover up, Jupiter in broad daylight. You'll have no trouble finding the pair if the sky is clear. Western Canada and most of the U.S. is in the observing path, except for New York and New England. Earlier that day the moon occults Saturn for equatorial Africa, India, and Indonesia.

August would be incomplete without the famous Perseid meteor shower. It's a great time to take the family into the dark countryside and lie down on a blanket to watch for swift shooting stars on Saturday night, the 11th to the 12th. You can expect a meteor every four or five minutes early in the evening and maybe double that amount later on. Unfortunately, the last quarter moon tarnishes the event for all-night meteor observers.

Beginners often start observing with small scopes in the warm summer months, learn to find the Ring Nebula and the famous Double Double, and then move on. But there's a lot more in Lyra to explore. Even from the city, small scopes can reveal a star cluster and a drop of stellar blood. If you're attending a star party this month, make sure you stay up late to spy periodic Comet Borrelly in the rich northern reaches of the Orion Milky Way.

**Venus and Jupiter hang low over the Statue of Liberty in November 1993.** Larry Landolfi



# 2001 August

3 The moon passes 3° south of Neptune, 3 P.M. EDT

4 Full moon is at 1:56 A.M. EDT
The moon passes 3° south of Uranus, 11 P.M. EDT

5 The moon is at apogee (252,444 miles from Earth), 5:05 P.M. EDT
Mercury is in superior conjunction, 6 P.M. EDT
Venus passes 1.2° south of Jupiter, 8 P.M. EDT (page 58)

12 Last quarter moon is at 3:53 A.M. EDT
Perseid meteor shower peaks (page 60)

13 Asteroid Dembowska is at opposition, 5 P.M. EDT
The moon passes 0.2° south of Saturn, 11 P.M. EDT

15 Uranus is at opposition, 11 A.M. EDT (page 58)
The moon passes 0.4° north of Jupiter, 4 P.M. EDT

16 The moon passes 1.9° north of Venus, 9 A.M. EDT

18 New moon is at 10:55 P.M. EDT

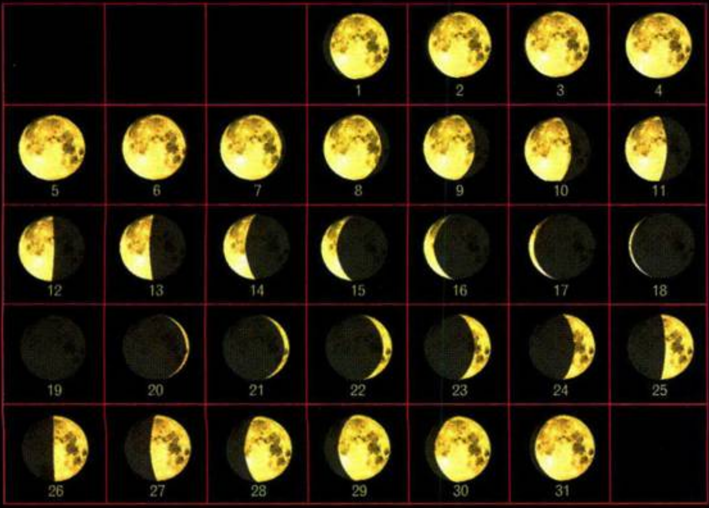
19 The moon is at perigee (221,927 miles from Earth), 1:41 A.M. EDT

22 Venus passes 7° south of Pollux, 9 A.M. EDT

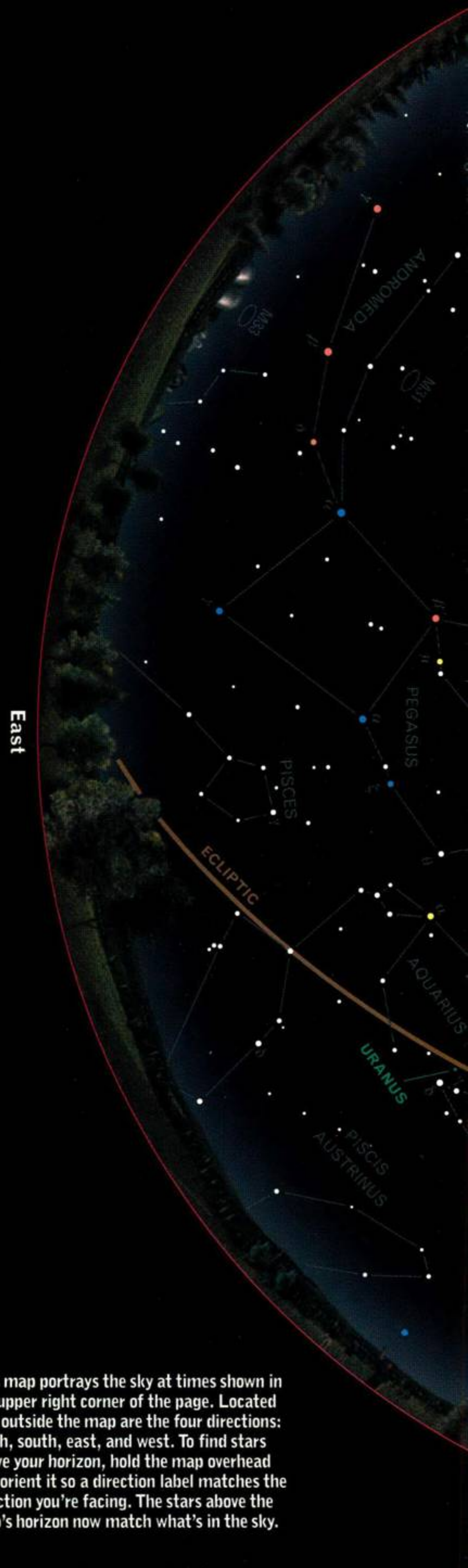
25 First quarter moon is at 3:55 P.M. EDT

27 The moon passes 5° north of Mars, 8 A.M. EDT

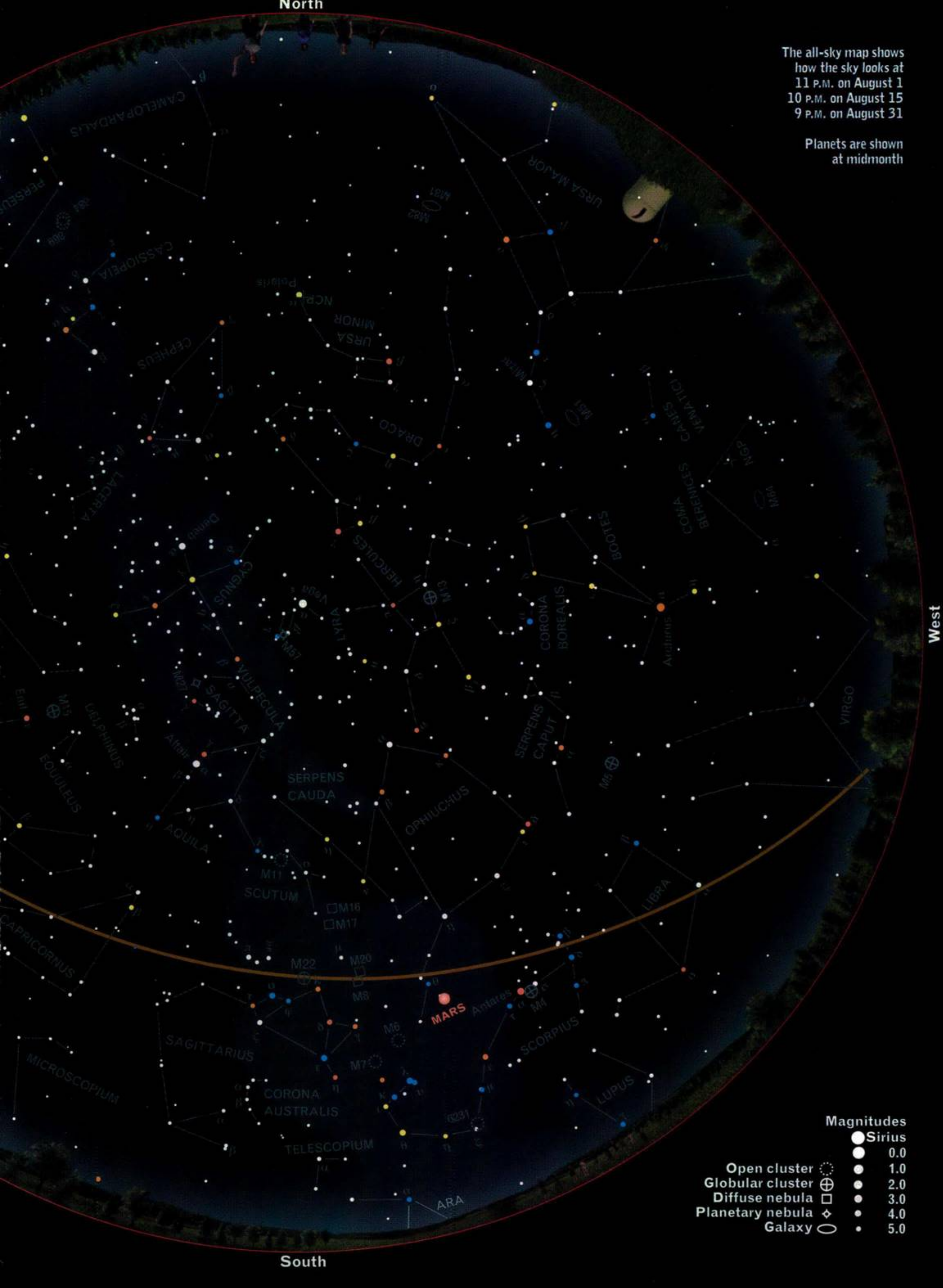
30 The moon passes 3° south of Neptune, 8 P.M. EDT



| SUN. | MON. | TUE. | WED. | THUR. | FRI. | SAT. |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |



**This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.**


North
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CAMELOPARDALIS
PERSEUS
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URSA MAJOR
M81
M82
Polaris
NCP
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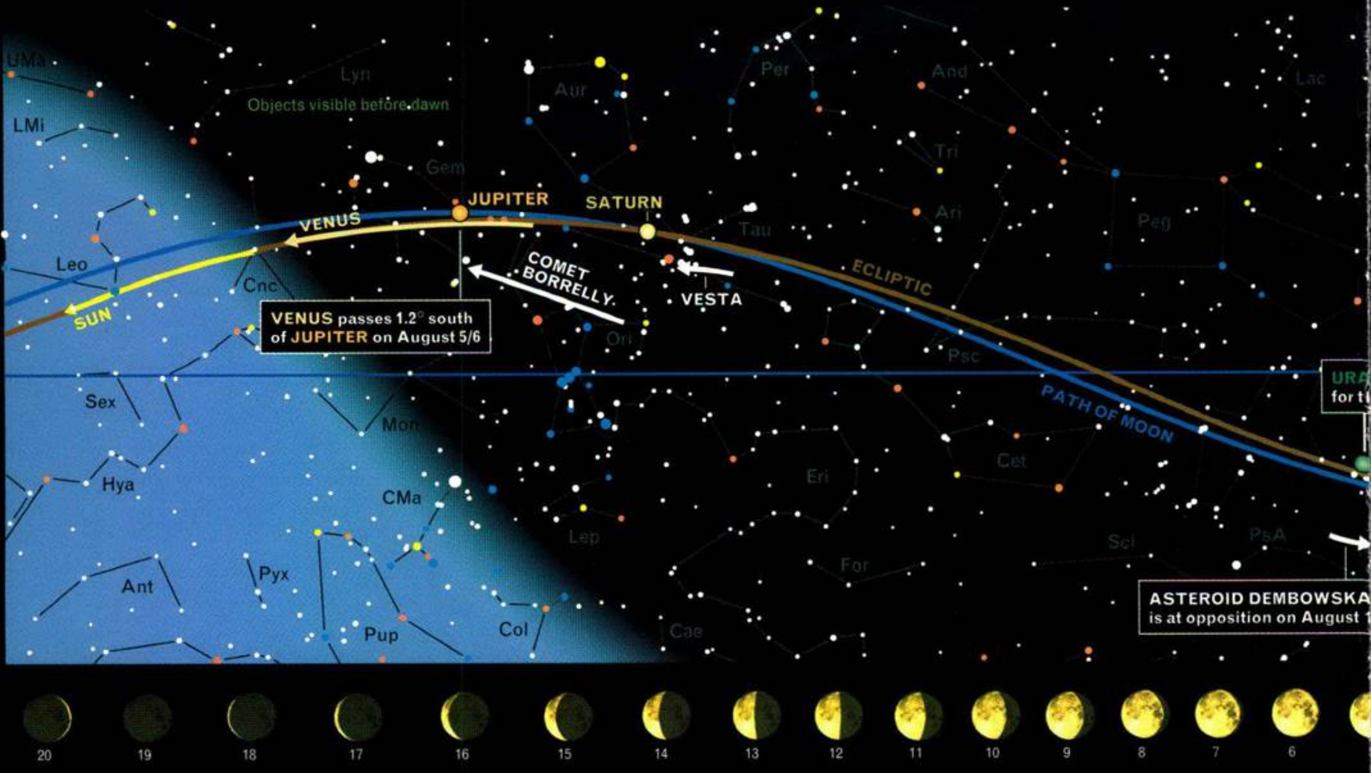
CEPHEUS
DRACO
Mizar
M51
CANES VENATICI
NGP
COMA BERENICES
M64
LACERTA
Deneb
CYGNUS
HERCULES
BOOTES
Vega
LYRA
M13
CORONA BOREALIS
Arcturus
M57
M27
SAGITTA
VULPECULA
Enif
M15
DELPHINUS
EQUULEUS
Altair
SERPENS CAPUT
VIRGO
M5
SERPENS CAUDA
OPHIUCHUS
AQUILA
M11
SCUTUM
LIBRA
M16
M17
CAPRICORNUS
M22
M20
M8
MARS
Antares
M4
SAGITTARIUS
M6
SCORPIUS
MICROSCOPIUM
M7
CORONA AUSTRALIS
LUPUS
6231
TELESCOPIUM
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
11 P.M. on August 1
10 P.M. on August 15
9 P.M. on August 31

Planets are shown
at midmonth

# Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objec


UMa
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Objects visible before dawn
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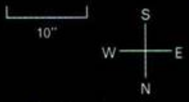
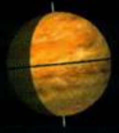
**VENUS** passes 1.2° south of **JUPITER** on August 5/6

**ASTEROID DEMBOWSKA** is at opposition on August 1

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

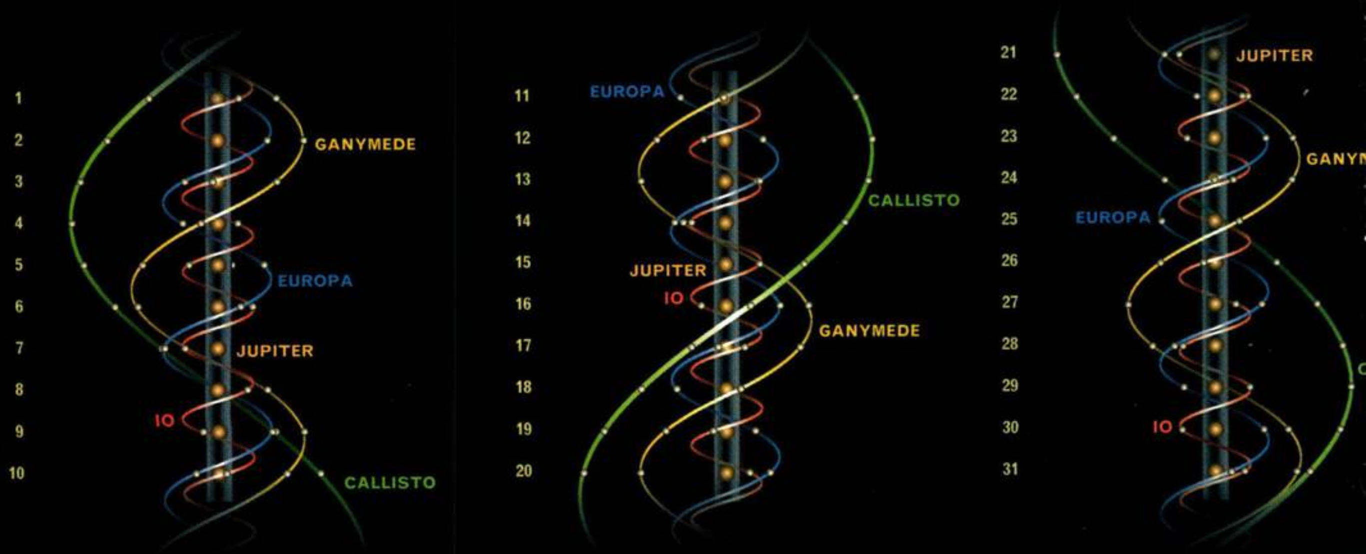
| **PLANETS** | **MERCURY** | **MERCURY** | **VENUS** | **MARS** | **MARS** |
|---|---|---|---|---|---|
| **Date** | August 15 | August 31 | August 15 | August 1 | August 31 |
| **Magnitude** | –1.0 | –0.2 | –4.0 | –1.5 | – 0.9 |
| **Angular Size** | 5.0" | 5.5" | 13.8" | 17.0" | 13.4" |
| **Illumination** | 95% | 81% | 77% | 91% | 86% |
| **Distance (AU) from Earth** | 1.345 | 1.222 | 1.210 | 0.550 | 0.698 |
| **Distance (AU) from Sun** | 0.383 | 0.454 | 0.723 | 1.417 | 1.394 |
| **Right Ascension (2000.0)** | 10h16.3m | 11h54.2m | 7h07.3m | 16h57.6m | 17h41.0m |
| **Declination (2000.0)** | 12°25' | 0°31' | 21°35' | –26°52' | –27°00' |



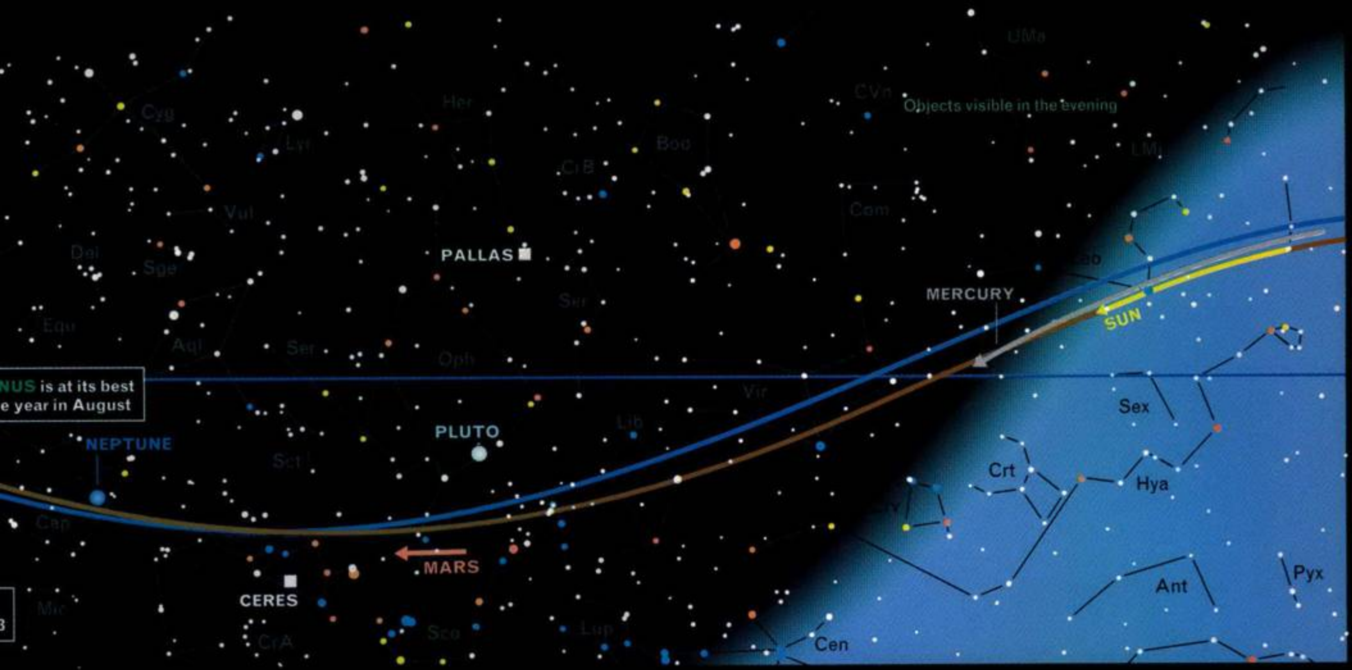


# Jupiter's Moons

Dots display positions of Galilean satellites at 5 A.M. EDT on date shown. South is at top to match the view in a telescope.



s during the month.


UMa
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Objects visible in the evening
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NEPTUNE
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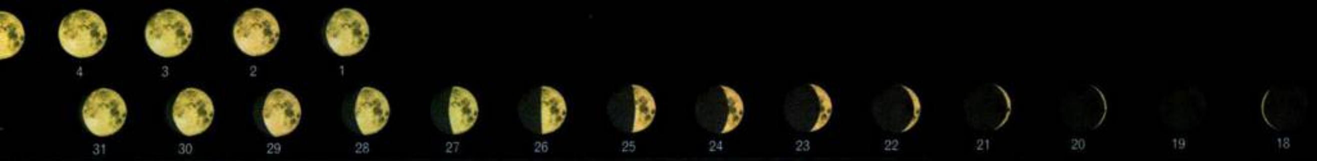
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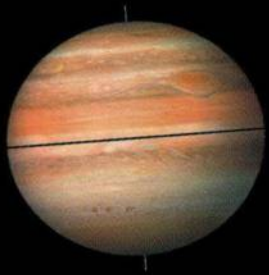

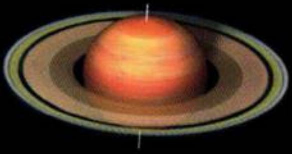

| JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|
| August 15 | August 15 | August 15 | August 15 | August 15 |
| –2.0 | 0.1 | 5.7 | 7.8 | 13.8 |
| 34.1" | 17.7" | 3.7" | 2.3" | 0.1" |
| 100% | 100% | 100% | 100% | 100% |
| 5.781 | 9.395 | 18.964 | 29.122 | 30.052 |
| 5.120 | 9.079 | 19.977 | 30.100 | 30.413 |
| 6h29.9m | 4h48.6m | 21h41.8m | 20h37.2m | 16h49.8m |
| 23°02' | 20°41' | –14°37' | –18°24' | –12°00' |

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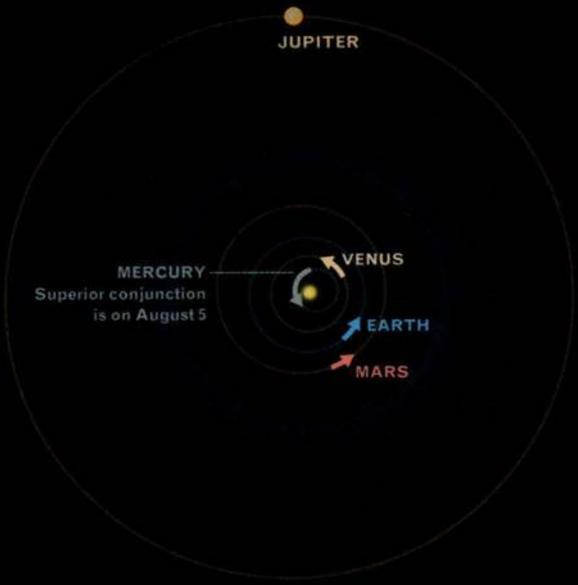
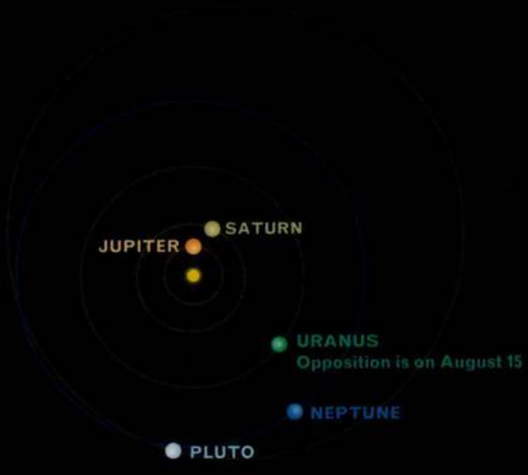
## The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


JUPITER
MERCURY
Superior conjunction
is on August 5
VENUS
EARTH
MARS


SATURN
JUPITER
URANUS
Opposition is on August 15
NEPTUNE
PLUTO

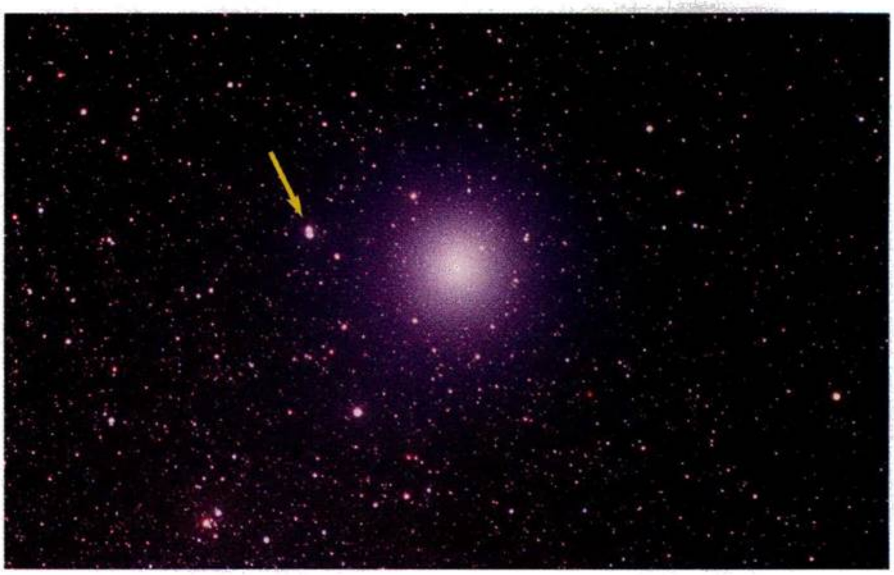
## The Wonders of Lyra

Crowning the dome of the sky on summer evenings is the lovely Lyra, adorned by the sparkling blue-white luminary Vega. For so small a constellation, there are many riches to uncover here. Little did I know this when I first began using my 4.5-inch Newtonian, because the instruction manual 25 years ago was silent when it came to pointing things out. At the time I was satisfied jumping around the sky, just to compare Vega's brilliant sapphire hue to Arcturus's topaz.

Moments after walking into an astronomy club, I was shown the "Double-Double," one of the most remarkable sights in the sky, and it was barely a hop from Vega. The finderscope and low-power view showed two equally bright, white stars. When my celestial tour guide boosted the power, he knew the sight of the two stars splitting into identical pairs was going to wow me.

Like many neophytes, I couldn't seem to do the final split with my own scope. The folks at the astronomy club chaperoned me through the ritual of collimation, the science of aligning the mirrors in a scope — and it wasn't so scary after all. Suddenly, I could split the Double-Double. I have yet to come across one of those classical 4.5-inch 900mm focal length scopes that couldn't rise to the occasion, even with old inferior Huygens eyepieces. Take another look: Are all the stellar components identical?

**The Ring Nebula (M57) in Lyra is the prototypical planetary nebula.** Jack B. Marling



**The famous "Double-Double," Epsilon Lyrae (arrow), is a treat for small scopes.** Alan Dyer

I'm still surprised at the number of veteran observers who don't take the time to fine-tune their optics. They're so eager to put eye to the sky that they accept a slightly blurry view of everything. If you find collimating a little too challenging at first, ask for help, and before long, you'll be helping others. You've paid a lot for that scope and waited a long time for this beautiful night, so make the most of it.

As for the famous Ring Nebula, M57, it looks stunning in books and certainly through the 200-inch Palomar telescope. But how about out in the field? My guide, grinning, eased an 8-inch scope a bit to the south and awaited my gasp.

As I peered into the eyepiece, there wasn't any color, but to a starry-eyed beginner, the small, pale, oval smoke ring was the most wondrous object in the sky. From the downtown section of a large city such as Montreal, M57 is visible in a 4.5-inch scope, which is pretty amazing.

There's no substitute for a good star atlas, because most amateur astronomers don't have the whole sky memorized. Lyra again took me by surprise, this time more than 10 years after I earned my stripes. Easily visible at low power in a small scope is the delightful star cluster Stephenson 1, right around Delta$^1$ ($\delta^1$) and Delta$^2$ ($\delta^2$) Lyrae, in the same binocular field as Vega. It may not be as splashy as a Messier cluster, but it has some color and stands out well in a wide, low-power field.

I should have known that the delights never end, despite 15 years' experience watching Lyra climb overhead. A variable-star observer called me to his 4-inch refractor one night to stun me. Smack in the middle of the field stood T Lyrae, a drop of blood anchored on the black sky.

I quickly looked in the finder to see Vega blazing back from the side of the view. T Lyrae owes its red hue to the carbon soot near its surface. It does change color a bit; perhaps you will be greeted by orange.

When looking for color, remember to use direct vision. Glancing off to the side with averted vision works well on the Ring Nebula, but color is best seen head-on in bright objects.

If you've got an eye for detail, direct it toward the variable star Beta (β) Lyrae — it's a naked-eye eclipsing binary. Compare its brightness every night to Gamma (γ) and Zeta (ζ) Lyrae, the two adjacent stars on the lozenge shape of Lyra. See if you can estimate its period before looking up the answer.

## Mars's Long Good-Bye, Uranus at Opposition

**Mars** continues its dominance of the evening sky. Look for the bright, red object low in the southern sky after sunset. The Red Planet begins the month shining at magnitude –1.4 but fades to –0.8 by August 31, due to the rapidly increasing distance between Earth and Mars. Mars lies 7° west of Antares, the orange-red colored star in Scorpius. As the month passes, this distance quickly increases.

You'll have about two hours of good martian viewing after sunset in early August before the planet falls too low. Mars sets in the west around local midnight and becomes increasingly difficult to observe due to its low altitude. Mars is particularly susceptible to atmospheric conditions due to its small size. Its apparent size as seen from Earth diminishes from 17" to 13" by the end of August.

On August 5, Mars passes 40' (just over one moon-width) due south of the globular cluster M19 for the second time in five weeks, although the nearby full moon will make viewing the star cluster difficult. Both objects will fit inside a low-power telescopic field of view. The planet continues its eastward path against the background stars during the rest of the month, traversing the southern reaches of Ophiuchus and heading for Sagittarius. You'll find Mars 7° southeast of a waxing first quarter moon on August 26.

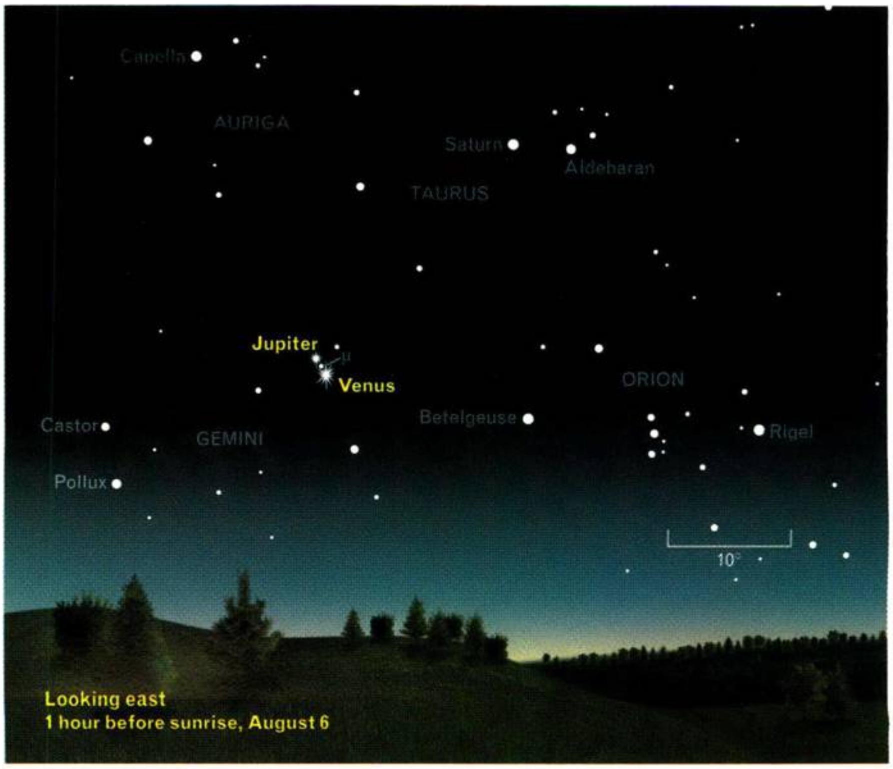
Don't wait any longer to get close-up views of Mars through a telescope. This month is your last chance for good shots at the planet. Seasons on Mars are beginning to change; during the month, more of the south polar cap will become visible as the northern hemisphere of the planet moves into fall, and the southern polar cap begins to show evidence of shrinkage. Since the number of hours for observing Mars is decreasing, the features visible on any given night are limited. For observers in the continental United States, Solis Lacus and the Tharsis Desert are on display in early August. Syrtis Major becomes visible during the last two weeks of the month.

**Neptune** reached opposition on July 30 and shines at magnitude 7.8 among the stars of Capricornus, the Sea-Goat. It is already above the southeastern horizon as soon as the sky becomes dark, and it's visible all night. Early August is the best time of year to catch the eighth planet from the sun. It lies in the same binocular or low-power telescopic field of view as the magnitude 5.1 star Upsilon (υ) Capricorni. Nightly viewing of the planet will show it gradually moving away from this star. Neptune currently lies 2.7 billion miles from Earth.

**Uranus**, the seventh planet from the sun, reaches opposition on August 15, making it visible almost all night. It's an easy binocular object this month, shining at magnitude 5.7 among the stars of Capricornus, the Sea-Goat. It lies in the same binocular field of view as the moon the day after full phase on August 5. On the same night Uranus lies directly between 44 Capricorni and 45 Capricorni, two stars of similar brightness to Uranus that lie close to Deneb Algedi, the magnitude 2.8 star at the northeastern end of Capricornus. The planet tracks to the west of this

### Central Meridian Longitudes on Mars for various dates at 10 P.M. Central Daylight Time

| Date August | CM Longitude | Principal Features |
|---|---|---|
| 5 | 105° | Solis Lacus, Tharsis Desert |
| 10 | 60° | Mare Acidalum, Chryse |
| 15 | 13° | Sinus Sabaeus |
| 20 | 325° | Hellas, Syrtis Major |
| 25 | 279° | Hellas, Syrtis Major |
| 30 | 230° | Mare Cimmerium |

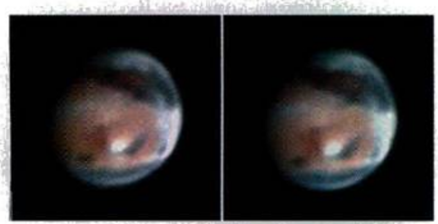


Looking east
1 hour before sunrise, August 6

group during August. Uranus exhibits a 3.7" bluish-green disk, just detectable in small telescopes.

A spectacular conjunction between **Jupiter** and **Venus**, the most dramatic of the year, occurs in the morning hours of August 6. The pair of planets, the two most brilliant in the sky, lie on either side of Mu (μ) Geminorum, a magnitude 2.9 star at the northwestern corner of Gemini. The two planets lie only 1.25° apart for this brief moment.

Rising just three hours before the sun, Venus is the brightest, shining at magnitude –4.5, and Jupiter competes with a respectable magnitude –2.0. A low-power eyepiece may show both planets at once, quite a rare sight. Try following the conjunction during daylight. With a polar-aligned telescope, set the telescope tracking the planets before sunrise, and check on their progress throughout the day.



**Mars on April 6, 2001, is centered on meridians of 207° and 209°.** Donald C. Parker

**Venus and Jupiter float majestically above a lone observer's scope.** Larry Landolfi

Alternatively, with care you can offset from the sun by checking their relative celestial positions and using the scope's setting circles to find the two planets. Make sure, of course, that you do not look through the telescope while the scope is pointing anywhere near the sun.

In the days running up to the Jupiter/Venus conjunction, you can see Venus close in on Jupiter each morning before sunrise. In the days following August 6, Venus moves quickly away from Jupiter as it descends into deepening twilight.

The moon hangs 6° west of Jupiter on August 15. Later the same day, during daylight, the moon occults Jupiter for observers in the continental United States. The event occurs at approximately 3:40 P.M. for observers in the central daylight time zone. It occurs earlier for western observers and later for eastern observers. Jupiter's disk takes more than one minute to disappear behind the moon's limb. Check with the International Occultation Timing Association's web page (lunar-occultations.com) for more accurate timings at your precise location.

On August 16, a slim crescent moon glides to within 2° of Venus. Rising three hours before the sun, the sight is visible for an additional couple of hours until the bright glow of the rising sun hides Venus and the moon from our view.

Far to the upper right of this brilliant pair is **Saturn**. It continues its lovely show with the attendant stars of the Hyades and the Pleiades. Saturn shines at its dimmest for the year at magnitude 0.2 and will begin to brighten as it progresses toward its end-of-year opposition. Another event awaits: The waning crescent moon occults Saturn for observers near the equator in Africa shortly before sunrise, and in daylight for observers in India and Indonesia.

# Meteors and Moons

**The most prominent crater on the moon, Copernicus delights in any scope.** Leo Aerts

### Summer Meteors

The presence of moonlight heavily affects the venerable Perseid meteor shower this year. By the time the radiant, the location in the sky from which the meteors appear to emanate, reaches a decent altitude, the last quarter moon is also high in the sky. Conditions are better for the early stages of the shower in late July and the latter stages during mid-August. However, since the Perseids often produce spectacular early-morning fireballs, it is worth spending a couple hours outside before dawn, even with the moon in the sky, on the night of peak activity. The broader peak might be experienced on both mornings of August 12 and 13.

Far better conditions exist for this year's Kappa Cygnid shower. A frequent companion to the Perseid display, the Kappa Cygnids peak on August 17, just two days before a new moon. This situation presents good dark skies to observe the shower, whose radiant lies in Cygnus the Swan. The members of this shower are slower moving than Perseids, often producing yellowish colored trails.

### Petite Full Moon

Does this month's full moon look a little smaller than normal to you? If you answered yes, you'd be right. The August 4 full moon coincides with apogee, the point in the moon's elliptical orbit around Earth that lies farthest from us. This and the September 2 full moon both coincide with apogee, when the moon will span 29.5'.

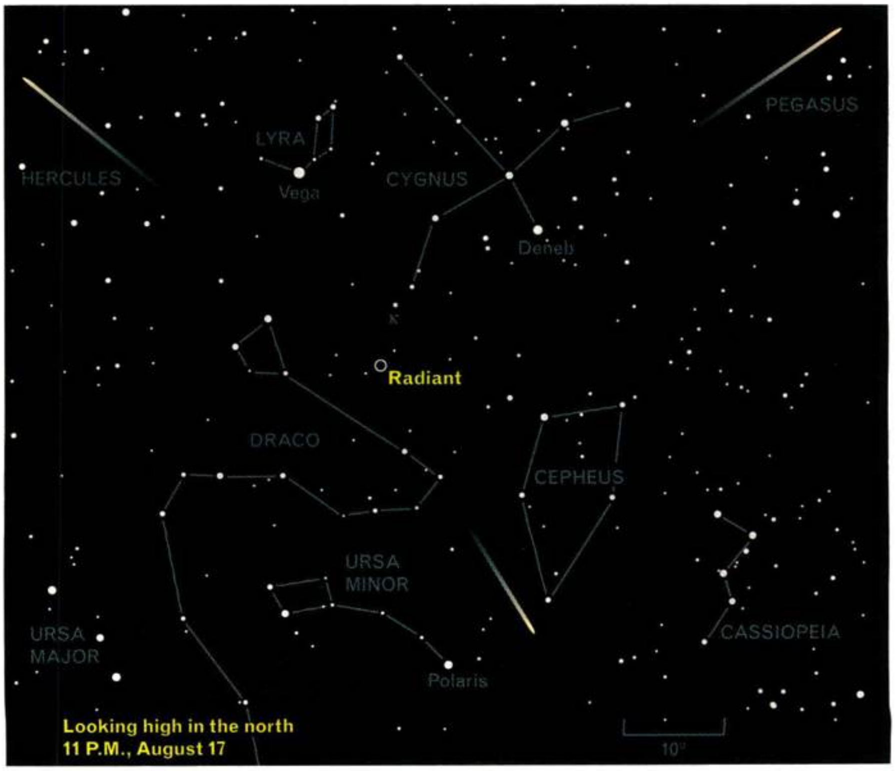
The largest the full moon can appear is about 33.5'. You'll have to wait until the first couple months of 2002 to see a moon that size. Try taking a photograph of this month's full moon, and again in six months' time using the same telephoto lens, and compare the size of the moon in the two photographs. The difference in size will be obvious.

### Darkness Descends on Copernicus

Since the moon interferes with the month's major meteor shower, here's a feature well-placed during days following the last quarter phase. On August 12, the 56-mile (93-km) wide crater Copernicus is getting ready for two weeks of darkness as the sun begins to set on this well-known feature. Watch on each morning from August 13 to August 14 and see the crater disappear into darkness. As the moon rises on August 14, the terminator (dividing line between day and night) will fall across the crater, and the floor of the crater will be in shadow. Return every hour to see the changes that take place.

The region around the crater will be revealed in stark contrast, with small rilles and chains of hills casting long shadows. Some of the secondary craters that formed on the ejecta blanket of Copernicus may also be seen. Small chains of craters around Copernicus were probably caused by debris, ejected from the original impact, which fell back to the moon.

At other times, Copernicus exhibits some of the finest traits of a major crater, such as central mountain peaks and terraced walls. Its highest peak reaches almost a mile above the crater floor. During these few days of August, you can watch as the shadows of the peaks grow and extend across the crater floor, something that takes a few hours if you catch the timing just right.



**Looking high in the north**
**11 P.M., August 17**

### Comet Borrelly Buzzes Orion

Walk through a field of telescopes in the wee hours of an August star party and you're sure to notice that many are pointed at the same object rising in the east. Periodic Comet Borrelly is swinging through the inner solar system on its seven-year orbit. It's hard to imagine a nicer way to end an all-nighter than to spot its diffuse glow in front of a rich starfield of the Milky Way in Orion as you inhale the gently scented dampness of the still morning air.

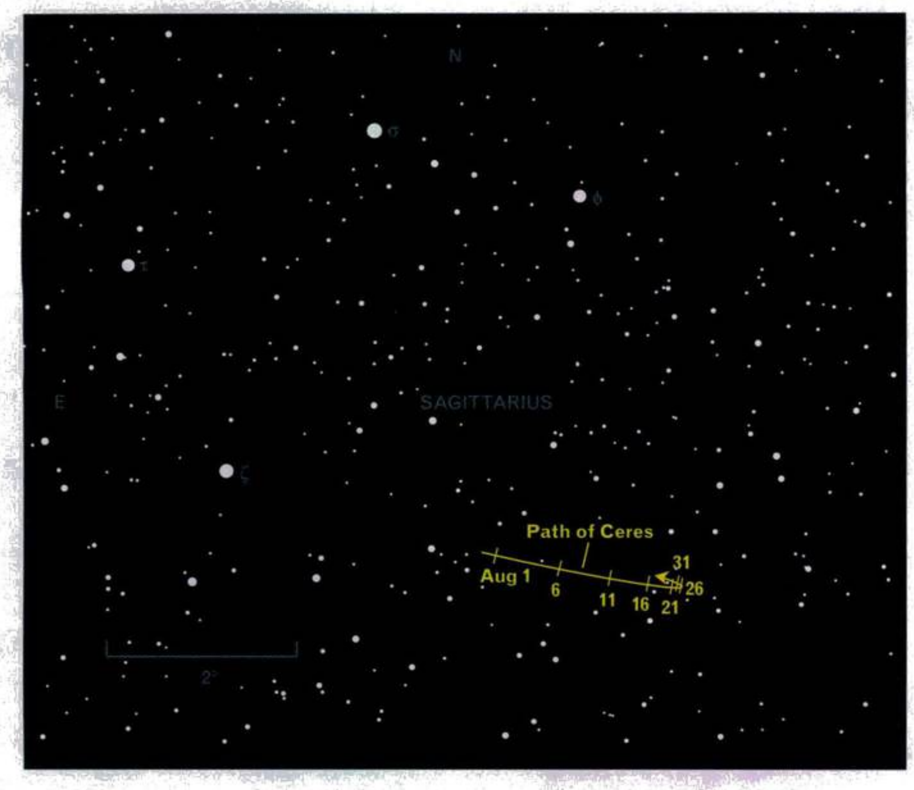
This time around, Borrelly won't grow bright enough for most binoculars. It will roughly be 10th to 11th magnitude, not quite reaching the tail end of the galaxies on the Messier deep-sky object list. Wait until the 17th for the moon to get out of the way, and make sure you're out under a nice country sky.

On Saturday morning, the 18th, Borrelly will be due north of the red giant star Betelgeuse, about one binocular field away. While you're in the area, you must check out the bright "37" star cluster. Remarkably, the stars of NGC 2169 lie in a pattern that resembles the number 37. If you use a diagonal on the scope, the stars may instead call to mind the Greek letters of a sorority house.

**Comet Borrelly streaked through a prominent apparition in 1987.** Abdul Hadi Marafie

Deep-sky photographers will want to take a portrait of Comet Borrely on the morning of the 23rd, when the dirty snowball lies only 30', the apparent width of the moon, north of the stardust open cluster NGC 2194. This cluster should also be a pretty sight, especially in scopes 8 inches and up, which can resolve the cluster into dozens of faint speckles.

No matter what size telescope you have, take the time to examine the comet at a wide range of magnifications. Sometimes jets lie hidden near the false nucleus and show up subtly at more than 120x. Will Borrelly's tail reach across 1° of sky? Use a dark cloth over your head to cut out stray light and slowly sweep the scope back and forth at low power. At high magnifications, look for traces of jet activity near the comet's inner coma.



### The Biggest Asteroid

When at its closest, the number one solar system rock (Ceres) is bright enough to see with the naked eye. This year, however, you'll need binoculars to spot the 600-mile (1000-km) wide asteroid. To put this in perspective, Ceres is about one-third the size of our moon, and half the diameter of Pluto.

Ceres is named after the goddess of agriculture, making August an appropriate time of year for observation. Through next month you will be able to locate it within the "teapot" asterism of Sagittarius. Once you recognize the pattern of anchor stars in the lower left of the teapot, Ceres will be a snap to find; at magnitude 7.8, it is brighter than the Milky Way background.

Here's a variation on the field sketch method of identifying asteroids: Instead of just one position against the background stars, you'll be able to make four or five, because Ceres takes that long to move the apparent diameter of the moon. A

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*Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.*

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# Voices In the Night

## *Talk your telescope into learning the sky with Astro-Physics's DigitalSky Voice software.*

**by Steve Edberg**

I'm not a big fan of computer-controlled telescopes. My telescopes require manual adjustments. Yet computer-controlled telescopes now comprise an integral part of amateur astronomy — a role that will only increase in the future. After all, it's fun to give an inanimate object a command and watch it respond. And although I approached this review of Astro-Physics's DigitalSky Voice software with trepidation, I came away pleasantly surprised.

So who should use DigitalSky Voice? Anyone who's ever seen a *Star Trek* episode and longed for the time when they could walk into a room and simply say, "Computer: On!" Anyone tired of fumbling with a keyboard, expecially with fingers that in winter (and even in summer in some places) are covered with layers of gloves, mittens, or both. Anyone with disabilities that preclude nimble finger movements.

I tested DigitalSky Voice (DSV) Version 2.02, which I upgraded to Version 2.02.18 via the Transporter Room of Astro-Physics's website. DSV's manual contains explicit instructions on using the software with a variety of telescope mounts. The software installed easily on both my stationary and laptop computers. While I found no apparent difference in performance, some instructions were not applicable to the Meade software I used, which was an unfortunate limitation for me.

In addition to the microphone recommended by Astro-Physics (Radio Shack's Pro 302 — catalog #33-3002), I tested several others. While the Pro 302 worked well on the desktop machine, it couldn't compete with the built-in microphone that came with my laptop computer. But I also found that other small microphones with no on/off switch transmitted inferior sound to the software.

I used my laptop and attached the Pro 302 to a Meade ETX-125EC telescope with an Autostar hand unit. The initialization process put the telescope and software through their respective start-up procedures. New or infrequent observers must always repeat these steps, a time-consuming (and often frustrating) task, especially for someone with limited observing opportunities.

I experienced this problem firsthand. I was ready to go — or so I thought. Although the speakers welcomed me and said the program was ready to proceed, the software wasn't hearing me. My retesting indicated that the microphone signals were not being received. I had to sift through obtuse software instructions to get it working.

Finally, I ordered the telescope to locate some of the objects listed. The voice interpreter worked the majority of the time. I found the "Confirm Notification for Telescope Movement" command valuable and that the software preferred to hear me say "go to" rather than just the name of my target. Processing time for voice instructions varies; expect to repeat messages occasionally.

Overall, DSV is easy to use, and makes observing sessions more efficient. However, keeping the many viewing options current for use at a whim will challenge all but the most computer-savvy observers. Also, not everything is voice-activated; plan on using the keyboard or telescope control paddle at times. I found that a night-vision setting would have been helpful when I needed to control the telescope via the keyboard.

So, if you like the idea of telling your telescope where to go, DigitalSky Voice is made for you. But learn the sky anyway — and impress family and friends with impromptu sky shows on clear, dark nights.

---

*Steve Edberg is a frequent contributor to* Astronomy *magazine.*

### DigitalSky Voice System Requirements

DigitalSky Voice software is compatible with Windows 95/98/NT. It requires a Pentium (or clone) 100 MHz processor, 32 MB of RAM, 70 MB of disk space, a serial port and cable, a minimum 16-bit sound card, and a microphone and port with an on/off switch. It must be used with a computer-controlled telescope mount, such as one of Astro-Physics's GTO mounts, or a Meade or Celestron International computerized mount, among others.

Astro-Physics, Inc. • 11250 Forest Hills Road • Rockford, Illinois 61115 • (815) 282-1513 • Fax: (815) 282-9847
http://www.astro-physics.com • Price: $175

Astronomy: Terri Field

# Aquila and Scutum

Artwork at left from *The Glorious Constellations*, © 1991, Harry N. Abrams, Inc.

*Dazzling clusters and nebulae decorate this celestial duo.*

**by Tom Polakis**

Warm summer months bring with them some of the year's most appealing nighttime skies. With the Milky Way boasting its richest star fields, many constellations offer observers numerous deep-sky surprises. Sandwiched between Sagittarius and Cygnus along the river of the Milky Way lies Aquila, the Eagle, and its tiny neighbor Scutum, the Shield. Although these two constellations contrast greatly, each offers a wide array of astronomical objects to fill those lazy summer nights.

Although Aquila contains few nebulae and clusters and is devoid of Messier objects, this large constellation holds many other celestial treats well-worth searching for. The nearby star Altair, flanked by the bright stars Beta (β) and Gamma (γ) Aquilae, serves as the starting point for navigating through Aquila. From a distance of 17 light-years, it shines with the light of 11 suns. A line drawn from Altair through the 3rd-magnitude stars Lambda (λ) and Delta (δ) Aquilae divides the constellation. Moving northwest of this line, the luminous band of the Milky Way becomes more and more prominent, while the starry glow dies off abruptly to the southeast where dim galaxies prevail.

Aquila's dividing line points to the diminutive constellation Scutum. Although it is one of the sky's five smallest constellations, Scutum is home to a bright star cloud and is loaded with interesting telescopic fields, including one of Messier's finest open clusters, an overlooked globular cluster, and some impressive dark nebulae. Scutum is a difficult constellation to trace; its brightest star, Alpha (α) Aquilae, glows at barely 4th magnitude, and its remaining bright stars are located against a brilliant background, making them hard to spot.

Our midsummer tour begins in Aquila, at the yellow star Gamma Aquilae. Using a low magnification, sweep just over 1° west of the bright star to land on the structured dark nebula **Barnard 143**. A complex of dark patches lies against a star-filled field, the most prominent of which is a narrow bar about 20' oriented east to west. Two more dark nebulae connect to it on the western end to form a U-shape. To the south in the same field lies **Barnard 142**, another dark nebula measuring 3' long and one-third as wide, making it more difficult to see. Look to the west of these nebulae to see a faint yet crowded star field.

Scanning 3° southwest brings the planetary nebula **NGC 6804** into view. Although it appears faint, a 6-inch telescope easily shows its 30" disk. At 200x, the planetary is quite diffuse, with a hazy edge, but a nebula filter improves the view a great deal. Larger telescopes begin to reveal ring structure around the 14th-magnitude central star; this structure appears mainly as arcs of a thin rim that appear brightest to the north and south of the star. Two other similarly luminous stars lie on the western and northeastern edges of the planetary.

Next, move the telescope parallel to the Milky Way's band 4° to discover **NGC 6781**. At a distance of 2,600 light-years, this sizeable planetary nebula appears nearly 2' across in the eyepiece. In an 8-inch telescope, the nebula stands out well against a star-filled background as a soft, round disk.

Alan Dyer

A 16-inch scope at 150x brings out the structure of a thick ring, which is bright along the southern rim. This rim breaks to the north, where the nebula fades gradually into the background sky. The asymmetry in brightness becomes most apparent when seen through a broad-band nebula filter.

At the apex of a long triangle with Epsilon (ε) and Zeta (ζ) Aquilae resides the nicely defined open cluster **NGC 6709**, located 4,000 light-years away. Small binoculars resolve the cluster well against a background crowded with stars. Approximately 50 stars of mostly 10th and 11th magnitudes scattered over a 15' area come into view through a 6-inch scope. Look for two double stars on the eastern edge of the cluster, with one displaying pretty blue and yellow hues.

Nearly twice as distant as NGC 6709 is the open cluster **NGC 6755**. At 100x, the cluster appears well-detached from the Milky Way, with two distinct, elongated groups of 11th- and 12th-magnitude stars split by a dark lane running from east to west. A tiny line of four stars, 20" long, runs along the eastern end of the southern-most group. Look for the open cluster **NGC 6756**, a 5' grouping of stars with a sharply concentrated center, only ½° to the northeast.

From NGC 6755, move the telescope 2.4° south and ½° west to find **NGC 6749**. Don't be discouraged if you don't spot it immediately, as this is one of the least-concentrated globular clusters known; its brightest stars glow dimly at only 16th magnitude. At a distance of 24,000 light-years, this halo object is heavily obscured by material in the plane of the Milky Way. A 13-inch telescope at a dark site barely shows NGC 6749 as a soft haze 2' across. But on a clear night, a 20-inch scope at 300x resolves many of its brightest stars.

Just 2° to the southeast lies a more typical globular cluster, **NGC 6760**, easily visible in an 11x80mm finderscope. A 10-inch scope at 200x reveals a broadly concentrated disk 3' across. Despite the brightness of NGC 6760, resolving its stars proves difficult, as the same aperture barely brings out a granular texture. But a telescope twice this size resolves approximately 40 individual stars around the periphery.

Save the challenging planetary nebula **NGC 6741** for a night when the air is steady. It shows up at low magnifications as a bright "star" that jumps into view when a nebula filter is placed in front of the eyepiece. At 300x, the tiny 6" disk of the planetary distinguishes itself well from a dense surrounding star field. But its magnitude 19 central star is invisible to backyard telescopes. Astronomers have dated NGC 6741 at 10,000 years old.

Scan 3° northeast of Lambda Aquilae to locate the large planetary nebula **NGC 6772**. In a 12-inch telescope, it appears to be a circular disk containing few interesting features, measuring about 1' across with a hazy edge and no sign of a central star. Larger scopes reveal this planetary as a ring with an irregularly bright southeastern edge. With a nebula filter in the eyepiece, it seems to be slightly oval, elongated in a north to south direction.

Moving 1.4° farther to the northeast brings you to another planetary nebula, **NGC 6778**. At 300x in an 8-inch scope, it is a bright oval disk measuring 15" by 10", elongated east to west. The disk has a hazy edge, but a larger telescope resolves it into two equally bright lobes, creating the appearance of a tiny dumbbell nebula. Using your lowest magnifications, you'll see the dark planetary nebula **Barnard 139**, a starless lane just to the north of NGC 6778.

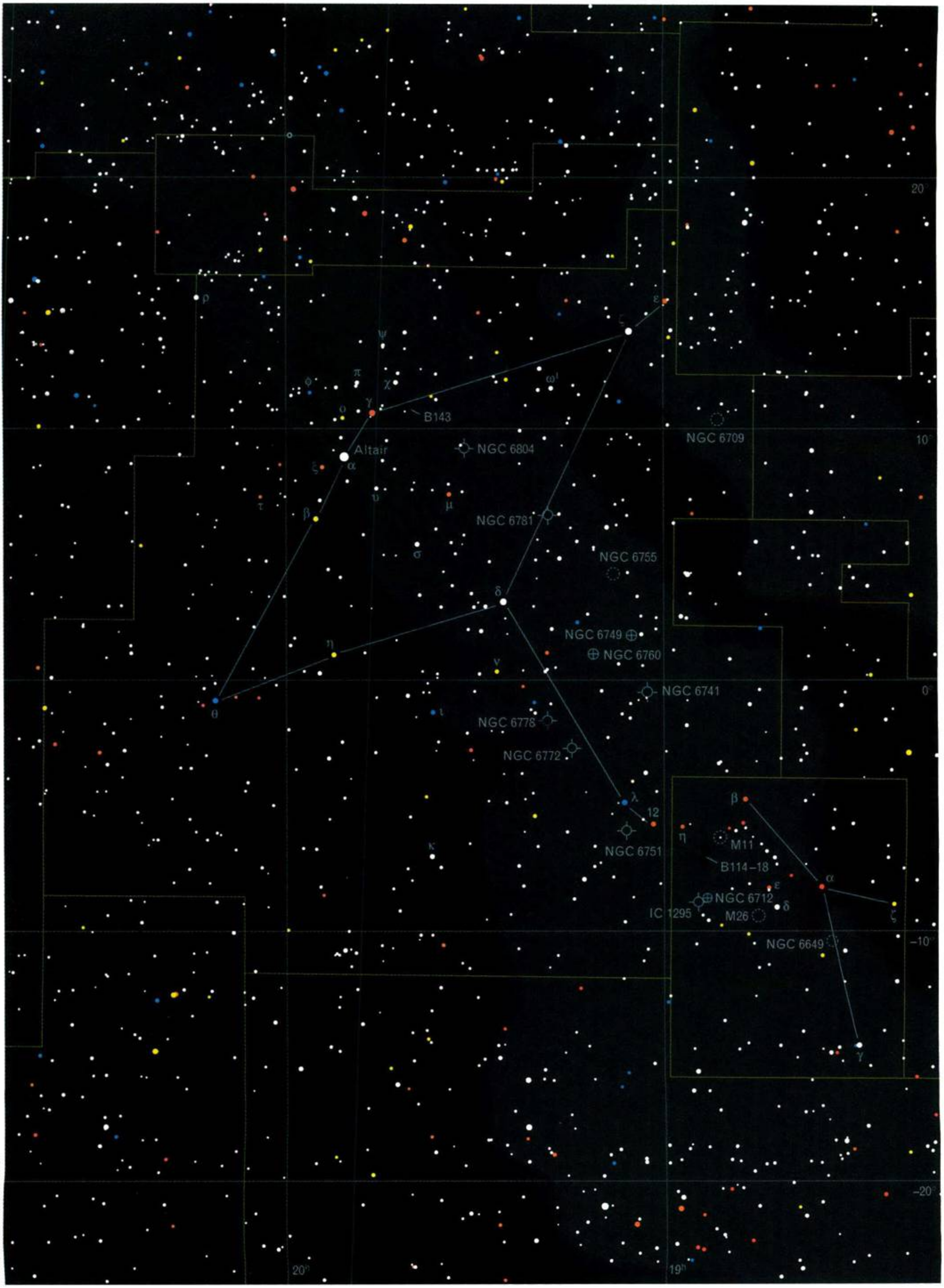
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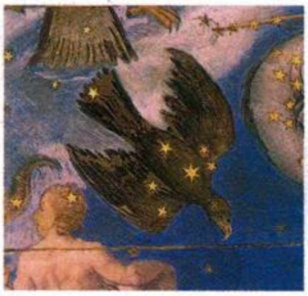
Illustration by Elisabeth Rowan

# The Eagle

"The day is done, and the darkness/ Falls from the wings of Night,/ As a feather is wafted downward/ From an eagle in his flight."
*—from "The Day is Done," by* Henry Wadsworth Longfellow (1807–1882)



The mythological tales revolving around Aquila, the Eagle, are as varied as the constellations themselves, ranging from stories of war and revenge, to love and romance. Adopted by Zeus as his own, the Eagle was sometimes referred to as the thunderbird, as its main purpose was to carry the thunderbolts of Zeus and retrieve them after they were thrown.

Extremely loyal to Zeus, the Eagle performed many other duties to help the chief god. When Zeus became taken with young Ganymede, a very handsome boy, the Eagle swooped down to abduct him and take him to Mount Olympus, where he then became the cup-bearer of the gods. Ganymede is honored by the constellation Aquarius, the Water-Carrier; the Eagle appears to be flying just above it in the nighttime sky.

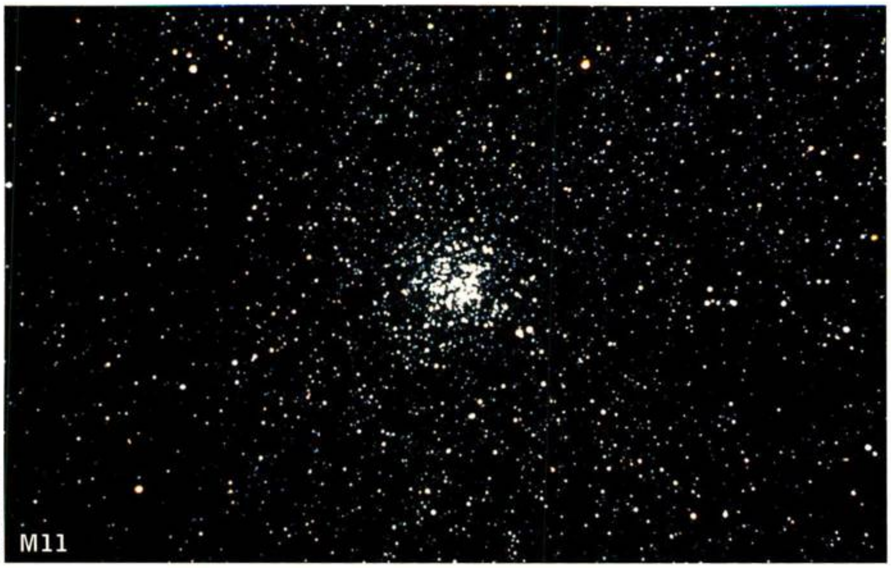
In addition to performing many good deeds, the Eagle also aided Zeus in carrying out punishments. When Prometheus, an immortal Titan, stole a ray of sunlight and presented it to humans as the gift of fire, Zeus became outraged that a power belonging only to the gods was now available to mortals. So to punish Prometheus, Zeus chained him to a rock, and sent the Eagle each day to chew on his liver. Because Prometheus could not die, it continuously grew back, giving him eternal suffering. The Eagle finally met its death when Hercules slew it with a poisoned arrow, in order to free Prometheus from his horrible punishment.

In reward for the Eagle's loyalty, Zeus set his faithful companion among the stars eternally. — *Elesa Janke*

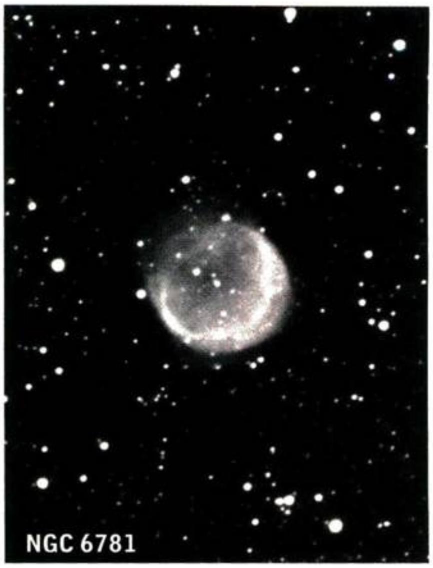
## Deep-Sky Objects in Aquila and Scutum

| Object | R. A. (2000.0) | Dec. | Mag. | Size/Sep./Per. | Type | Notes |
|---|---|---|---|---|---|---|
| NGC 6649 | 18h33.5m | –10°24' | 8.9 | 6.6' | OC | |
| M26 (NGC 6694) | 18h45.2m | –9°24' | 8.0 | 14' | OC | |
| M11 (NGC 6705) | 18h51.1m | –6°16' | 5.8 | 13' | OC | Wild Duck Cluster |
| NGC 6709 | 18h51.5m | 10°21' | 6.7 | 13' | OC | |
| NGC 6712 | 18h53.1m | –8°42' | 8.2 | 7.2' | GC | |
| B114–B118 | 18h53.2m | –6°58' | — | 6' | DN | |
| IC 1295 | 18h54.6m | –8°50' | — | 86" | PN | |
| NGC 6741 | 19h02.6m | –0°27' | 11.4 | 6" | PN | |
| NGC 6749 | 19h05.1m | 1°47' | 12.4 | 6.3' | GC | |
| NGC 6751 | 19h05.9m | –6°00' | 11.9 | 20" | PN | |
| NGC 6755 | 19h07.8m | 4°14' | 7.5 | 14' | OC | |
| NGC 6760 | 19h11.2m | 1°02' | 9.1 | 6.6' | GC | |
| NGC 6772 | 19h14.6m | –2°42' | 12.7 | 62" | PN | |
| NGC 6778 | 19h18.4m | –1°36' | 12.3 | 16" | PN | |
| NGC 6781 | 19h18.4m | 6°33' | 11.4 | 109" | PN | |
| NGC 6804 | 19h31.6m | 9°13' | 12.0 | 31" | PN | |
| B143 | 19h41.4m | 11°01' | — | 40' | DN | |

**Object:** Designation in NGC or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Popular names.


M11

Lee C. Coombs


NGC 6781

Kim Zussman

Our tour through Aquila ends with the planetary nebula **NGC 6751**, easily found at the apex of an equilateral triangle with Lambda and 12 Aquilae. It shows up as a circular disk 30" across, with a 13th –magnitude star shining just beyond the eastern edge. The darkness immediately surrounding the 14th-magnitude central star indicates that the planetary is another thick ring. Deep images of NGC 6751 bring out three concentric shells surrounding the central star; the brightest shell, about 0.5 light-years across, has been dated at 2,700 years old.

After Aquila, a treat awaits in neighboring Scutum—**M11** (NGC 6705), one of the sky's most spectacular open clusters. It is faintly visible with the naked eye by using Lambda and 12 Aquilae as pointers to the area. English observer William Smyth coined the name "The Wild Duck Cluster," making note of the cluster's "wedge" shape. But some modern observers see it as more square in form. Small, sharp refractors reveal M11 nicely, due to a couple dozen stars that shine brighter than 11th magnitude. The 6' core, packed densely with stars, nearly resembles a globular cluster. Streamers of stars surround this region in all directions. Nearly centered in M11 is an 8th-magnitude star that stands out among the hundreds of fainter stars. Dark lanes and a prominent dark void only 1' west of the center traverse the cluster.

NGC 6712

Jeffrey L. Jones

The second open cluster identified by Messier in Scutum, **M26** (NGC 6694), proves more difficult to locate than almost any other object in the Messier catalog. A pair of 11x80mm binoculars barely brings it into view. Through an average-sized telescope, M26 appears as a tight group of several dozen stars between 11th and 13th magnitude, occupying a space 7' across. Larger scopes bring up the fainter background stars.

A little more than 2° south of Alpha Scuti lies **NGC 6649**, a modest open cluster made more impressive by the lack of background stars. Situated 5,200 light-years from the sun against a dark obscuration at the western edge of Scutum, the cluster contains only 40 faint stars in a 6' area, but they stand out nicely against the dark backdrop.

An often-overlooked globular cluster, **NGC 6712**, is next on our tour. Bright enough to be visible in an 11x80mm finderscope as a nonstellar object, NGC 6712 appears to be moderately concentrated with little star resolution in a 6-inch scope at 100x. A 13-inch telescope resolves the cluster fully, presenting it against an exceptionally rich background star field. Although it is placed in the plane of the Milky Way and near its center, it is not one of our galaxy's disk globular clusters; in fact, it is plunging through the plane of the Milky Way at a distance of 21,000 light-years.

Look for the planetary nebula **IC 1295** just to the east-southeast of NGC 6712. With a nebula filter in an 8-inch telescope, the two disparate objects look quite similar. In a 13-inch scope, IC 1295 is a circular disk over 1' across with a subtly darker center. Larger apertures bring out the thick ring. Look 6' to the southwest of IC 1295 to locate the stellar planetary nebula Kohoutek 4-8, an apparent star that becomes visible through a nebula filter.

Return to M11 and move the telescope ½° to the southeast to find our final target, **Barnard 118**. This dark nebula, visible in low magnifications, appears as a starless lane about ½° long and only 5' wide that extends from north to south. The starry backdrop gives the correct impression that the dark nebula is in the foreground.

Before departing Scutum, be sure to put in your widest-field eyepiece and just scan the constellation.The Scutum stars are in an inner spiral arm of the galaxy, and appear best in small scopes. The incredible star fields of Scutum just may become your favorite sweeping grounds in the summer sky. ■

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*Tom Polakis is an aerospace engineer living in Tempe, Arizona, whose favorite astronomical pursuits are deep-sky observing and photography.*

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Glowing stellar remains cradle the degenerate core of an ancient sun in the planetary nebula NGC 2440.

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### What's the best estimate of the number of atoms in the universe? What will happen to the atoms in our bodies when we die? When the sun dies? — *Roy E. Franklin, Norman, Oklahoma*

The answer depends on how you choose to define the universe. The observable portion of our universe extends to a distance of about 12 billion light-years from Earth. Within this volume — a sphere with a radius of 12 billion light-years, centered on the solar system — the total number of atoms is indeed finite, with a good working estimate being $10^{78}$ (that's 1 followed by 78 zeros).

When we die, the atoms within our bodies return to the supply of atoms maintained by Earth. When the sun dies, about 7 billion years from now, it will first swell up to become a red giant, engulfing and incinerating Earth in the process. During the sun's planetary nebula phase, it will shed about half of its mass back into the interstellar medium. Therefore, about half of the sun's atoms are recycled into space.

The remaining atoms are confined to the degenerate stellar remnant left behind after solar evolution has run its course. This ultracompact body — a white dwarf containing roughly half a solar mass — will endure until its constituent protons decay into various subatomic particles. At present, the time scale for proton decay remains unknown, but current experiments indicate that proton lifetimes may exceed $10^{33}$ years. — *Fred Adams, University of Michigan department of physics. He is coauthor of* The Five Ages of the Universe: Inside the Physics of Eternity *(New York: The Free Press, 1999).*

### What's the recommended magnification for viewing globular clusters or nebulae with a 6-inch scope? — *Sean Hiscock, Labrador City, Newfoundland, Canada*

Consider M13, a bright globular star cluster in the constellation Hercules. Binoculars show it as a glowing globe of light nestled in the strongman's torso. This is a big object, at least a third the moon's diameter. Even your eyes show it as a 6th-magnitude star a third of the way up Hercules' western side.

But to really see M13, with stars resolved at the edges, you'll need to settle into the 6-inch telescope category — perhaps even larger. A typical small-aperture telescope (4-inch) theoretically resolves details 1.1" across. But jump to an 8-inch aperture and the resolution can be as good as 0.57," nearly twice the resolving power.

Magnification goes arm-in-arm with resolution. It lets you spread a quarry's image across an entire field of view so you can pick out tight details. But keep one rule of thumb in mind when increasing the power: Never exceed 50x to 60x per inch of aperture. This means a 6-inch scope's power limit falls between 300x and 360x. Anything beyond that causes images to appear faint and mushy.

An unsteady atmosphere will often keep you from ever reaching a scope's theoretical power limit. Moreover, atmospheric turbulence imposes a 1" resolution limit on even the best telescopes. — *John Shibley, contributing editor*

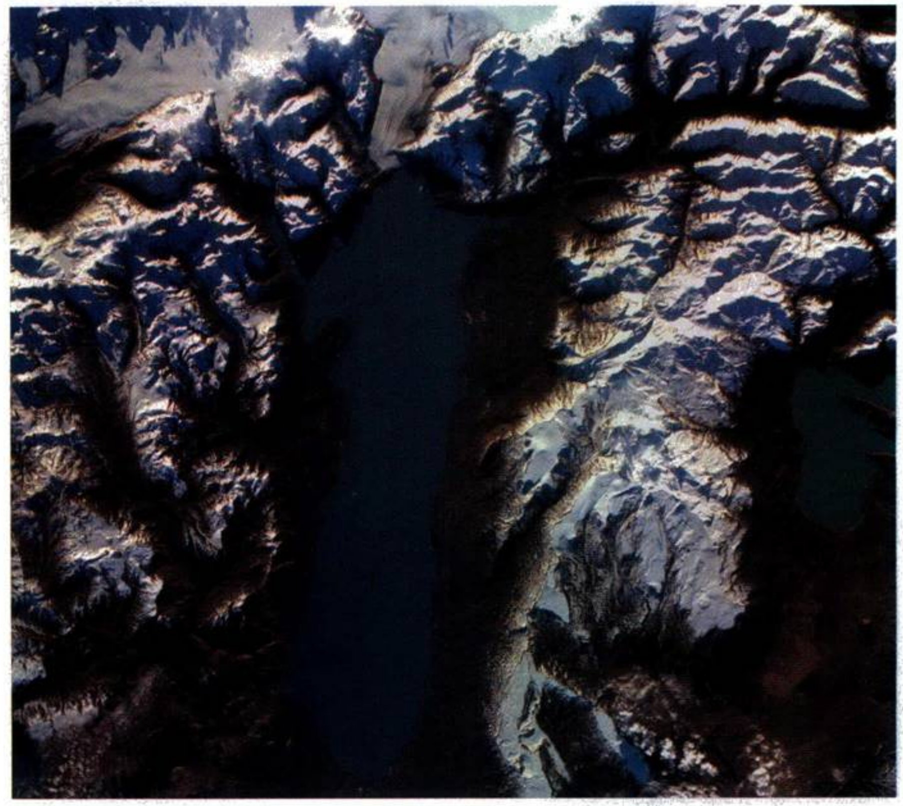
### What equipment or conditions are required to spot Sirius B? — *Heinke le Roux, Durbanville, South Africa*

In 1844, Friedrich Bessell managed to detect the faint star Sirius B through its gravitational influence on the much brighter Sirius A, which was seen to oscillate against the background stars. But it wasn't until 1862 that Sirius B was directly observed. The famous telescope maker Alvan Clark holds the distinction of being first to spot Sirius B while testing the new 18-inch refractor at Northwestern University's Dearborn Observatory.

Sirius A, the brightest star in the night sky, is a normal main sequence (hydrogen-fusing) star with about twice the mass of the sun and a surface temperature around 9000 Kelvin. Sirius B is 10 magnitudes (a factor of 10,000 times) fainter, but hotter than Sirius A. Astronomers now know that Sirius B is a solar-mass white dwarf with an average density more than a million times that of the sun. The pair orbit each other every 50 years with a separation that ranges from 3" to 11." Currently, their separation is 5" and will reach its maximum in 20 years.

While the angular separation of Sirius A and B falls easily within the range of a small telescope, the brightness difference makes Sirius B very difficult to see. What's more, the variable separation of the two stars heavily influences Sirius B's potential visibility.

Robert Burnham Jr., in his *Celestial Handbook*, states that he was able to see it with the Lowell 24-inch refractor stopped down to six inches, and that he observed it "on many occasions with a 10-inch reflector." The most important requirement, he says, is absolute clarity and steadiness of sky. — *Jim Kaler, University of Illinois. He describes a different star each week on his website at www.astro.uiuc.edu/~kaler/sow/sow.html.*



NASA

Glacial thumbprints of an ancient Ice Age linger about Argentina's Lake Viedma.

## What do we know about the onset of Ice Ages and their relation to Earth's orbit and tilt with respect to the sun? *— Bill Fisher, Hickory, North Carolina*

An Ice Age, or Continental Glaciation, occurs when the average temperature over a large land mass drops so low that winter snow buildup doesn't melt. An area's average temperature is determined primarily by how much solar energy it receives, which depends on the tilt of Earth's rotation axis and the distance between Earth and the sun.

Recently, Serbian mathematician Milutin Milankovitch proposed a connection between the occurrence of Ice Ages and the interaction of three astronomical cycles, each of which influences the amount of solar energy that Earth receives.

The shortest of these cycles is the precession of Earth's rotation axis with respect to Earth's farthest position from the sun. Every 21,000 years, Earth's axis is tilted away from the sun at the same time that Earth is at its farthest point from the sun. At these times, because Earth moves slower when it is farther from the sun, Earth spends more time at large distances, yielding longer, colder winters for the Northern Hemisphere.

The second cycle arises because Earth's axis does not maintain a constant tilt with respect to Earth's orbit around the sun. The angle between the axis and a vertical to the orbital plane is about 23.4° at present, but can vary from about 22° to 24° over a 41,000-year cycle. Greater angles correspond to larger seasonal changes.

The longest of the three cycles is the variation of Earth's orbital eccentricity. The eccentricity is a measure of the difference between Earth's closest and farthest positions from the sun. A greater eccentricity implies a larger variation in solar energy received. Since Earth spends more time at greater distances, a high eccentricity means less energy strikes Earth, on average. Earth's eccentricity varies, from near zero to about three times its present value of 0.017, with a period of about 100,000 years.

The combination of these effects seems to explain the occurrences of Ice Ages for the past 600,000 years. Still, other factors might also be involved. The amount of sunlight reflected back into space, the existence of a polar continent, levels of atmospheric carbon dioxide, and the motion of the solar system through the spiral arms of the Milky Way Galaxy could all influence global climate conditions.

A complete explanation may very well include contributions from some or all of these factors, and others. — *Jim Guinn, Lab Supervisor for Physics and Astronomy, Georgia Perimeter College, Clarkston Campus*

Ron Mikkelson

Lost in the light: The pale glow of Sirius B is dwarfed by the brilliance of its A-list companion.

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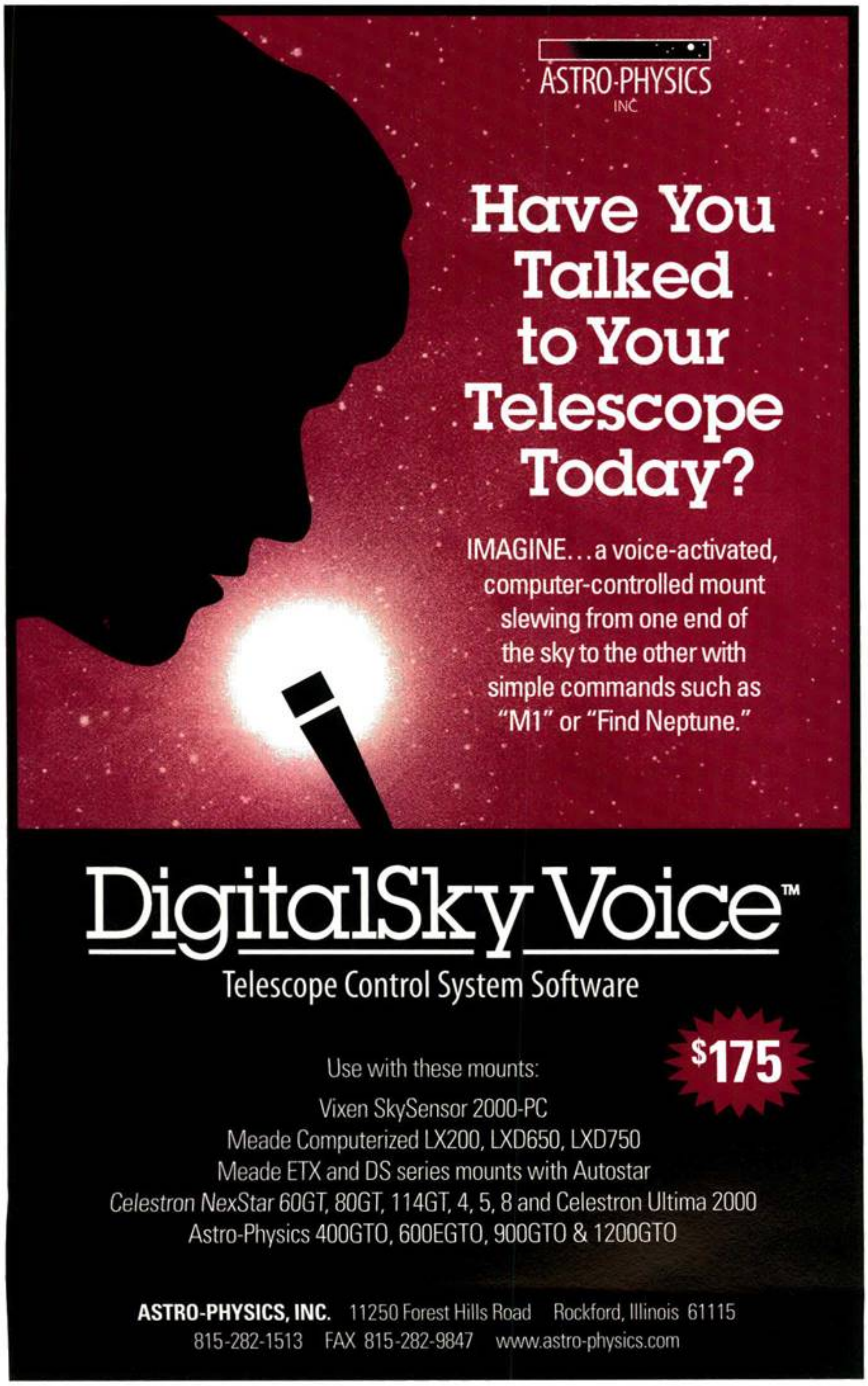

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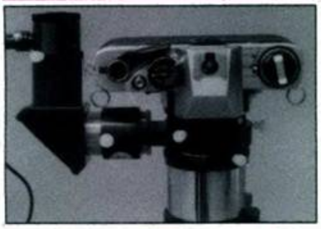

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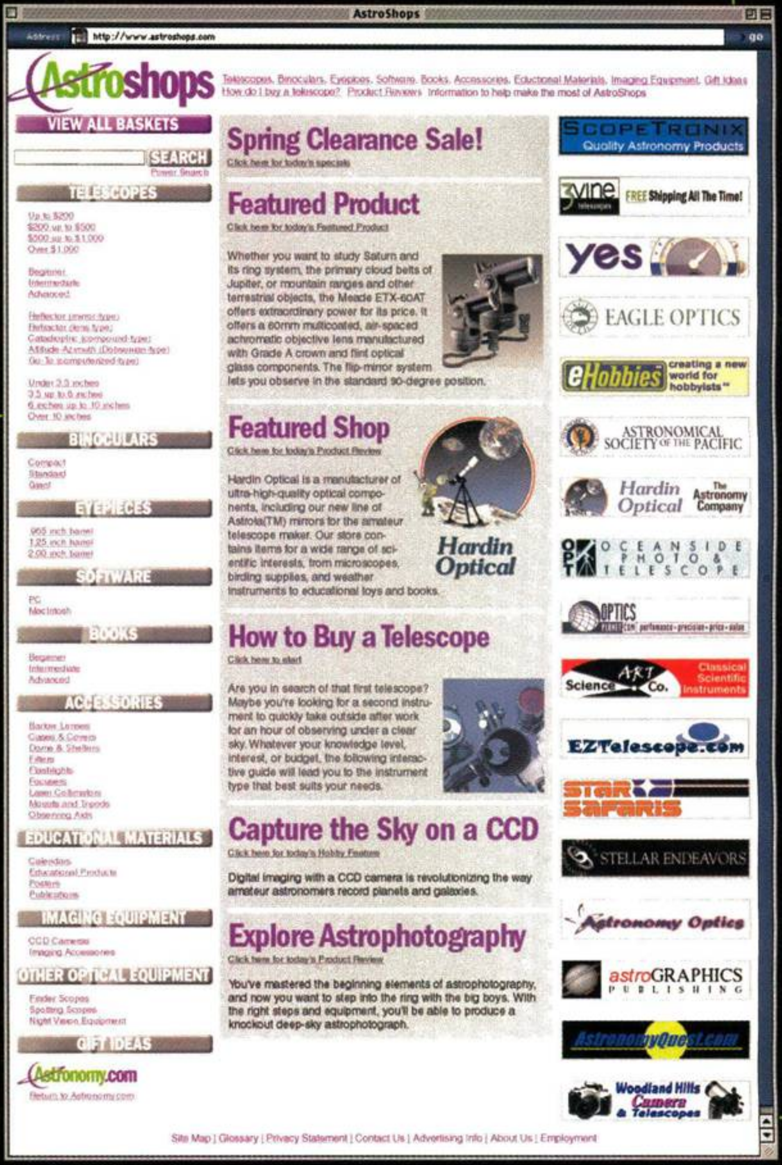

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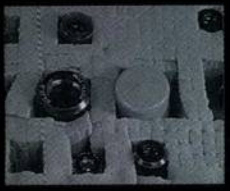

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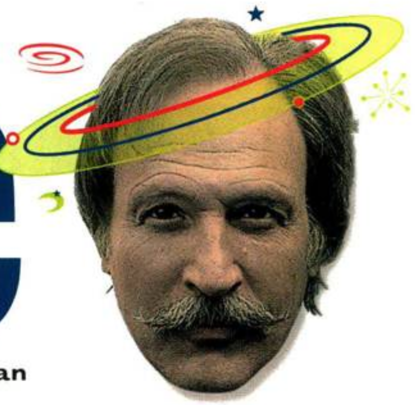
# strange Universe



by Bob Berman

## Quick Trip to Andromeda

What's the strangest, most mysterious aspect of this amazing universe? There's no shortage of candidates, but one really knocks my socks off. Its exploration requires a quick peek into the realm that surrounds the speed of light, which until recently seemed like the universe's absolute speed limit.

As we tiptoe into the new millennium, we're confronted with a surprising question: Has lightspeed lost its sovereignty? Come along: Something truly peculiar is going on. But first, a little background.

In 1905, Einstein gave meaning to a wild observation made during the previous few decades by Lorentz, Fitzgerald, and others. They had all realized that light travels at a constant speed and understood how profoundly remarkable that fact is. It means that photons from the headlights of a rapidly approaching car strike you at light's unwavering rate of 186,282.4 miles per second, as if the car wasn't moving. Earth's orbit propels us toward Deneb in June but we zoom away from it in December, yet its light forever hits us at the same speed and acts as if we're stationary. Imagine if wind acted like such a constant and felt like an unvarying gentle breeze regardless of whether you were stationary or holding your arm out the window of a fast-moving car. Right from the get-go, light starts out as strange and unique.

Of course, there's also the issue of what, exactly, light is.

In the Standard Model of How Things Work, a photon is a force-carrying particle, a visible sign that electromagnetism is doing its thing. Encountering an object, a photon acts like a massless particle, a bullet that weighs nothing, whose power depends on its color. While on its merry way between destinations, it's probably better to visualize it as a wave of energy, a magnetic field oscillating at right angles to an electric field. Each field creates the next and the combined electromagnetic wave zooms along at its unvarying speed.

Recently, researchers made headlines by dramatically slowing light. But we've always known that light automatically slows down when traversing air, water, or other dense media. Sunlight going through your window glass decelerates to about 120,000 miles per second and then instantaneously speeds up again once it's through. Outside a vacuum, particles readily exceed light's velocity. Electrons jazzed by powerful magnetic fields near some massive stars (the synchrotron process) can be hurled through a nebula faster than light can move in that medium. This creates a beautiful blue shock wave called Cerenkov radiation as the particle breaks the "light barrier." Light is strange, but we adapt to it.

In truly dense but translucent materials under certain conditions, light can be brought to a near halt (but not a full stop, as some newspapers wrongly reported last fall). Still, photons have recently been slowed to 38 miles per hour. Imagine — light that wouldn't even get a ticket on the freeway. Through it all, light's sovereignty in a vacuum has never been seriously challenged — until now.

Fast-forward to the odd world of Quantum Mechanics. This is a realm that makes Alice's adventures seem like a tame walk in the park, a Wonderland where particles can simultaneously exist and not exist, only to spring into reality as soon as someone takes a look. But wait, it gets worse. A number of physicists accept the "many worlds" explanation for quantum phenomena, believing that there is a separate universe for each option. If you measure an electron, you've forced it to make a choice as to what state it's in, where it exists or how it's moving. Actually, that's not accurate — it hasn't made a choice. Rather, you have suddenly joined the universe where it exists in the state you observe it to be. Another you inhabits a separate universe where you observe the electron in a different place or state.

So maybe you really did attend the prom with the captain of the football team or the head cheerleader in another universe. (Theorists unhappy with many simultaneous realities have created equally incredible alternatives to the many worlds explanation, but none has been widely accepted.)

In 1935, Albert Einstein, Boris Podolsky, and Nathan Rosen wrote a now-famous paper in which they addressed an aspect of Quantum Theory that was bizarre even by quantum standards. Examining the prediction that particles created together ("entangled") can somehow know what the other is doing, the physicists argued that such parallel behavior must be due to local effects, rather than some sort of "spooky action at a distance." The paper was so celebrated that such synchronized quantum antics became known as "EPR correlations."

But recent experiments have shown that Einstein was wrong. In 1997, a Geneva researcher named Nicholas Gisin created pairs of entangled photons and sent them flying apart along optical fibers. When one encountered the researcher's mirrors and was forced to make a random choice as to whether to go one way or the other, its entangled twin, seven miles away, always instantaneously acted in unison and took the same option.

"Instantaneous" is the key word here. The reaction of the twin was not delayed by the amount of time that light would have traversed those seven miles — it happened at least ten thousand times faster, which was the experiment's testing limit. The echoed behavior was presumably simultaneous. Indeed, Quantum Theory predicts that an entangled particle knows what its twin is doing and instantly mimics its actions even if the pair live in separate galaxies billions of light-years apart.

This is so bizarre, with implications so enormous, it has driven some physicists to a frantic search for loopholes. A few months ago, National Institute of Standards and Technology researcher David Wineland eliminated one of the main criticisms, expressed by those who thought that the previous experiments failed to detect enough of the particle-events.

As reported in the journal *Nature* this February, Wineland used beryllium ions and a very high detector efficiency to observe a large enough percentage of the in-sync events to seal the case. So this fantastic behavior is a fact. But how can a material object instantly dictate how another must act or exist if they are separated by large distances? It gets more and more curious. Few physicists think that some previously unimagined interaction or force is responsible. Striving to understand, I recently asked Wineland what he thought, and he expressed an increasingly accepted conclusion: "There really is some sort of spooky action at a distance." Of course, we both knew this clarifies nothing.

So there it is. Particles and photons — matter and energy — apparently transmit knowledge across the entire universe instantly. Light travel time is no longer the limit. Some physicists say that this does not violate relativity because we cannot send information faster than light, since the "sending" particle's information is governed by chance and is not controllable. But it seems to me that we're walking a fine line about what constitutes "information." Something is being conveyed instantaneously.

I'll leave the scientific (and any philosophical or metaphysical) implications up to you. Meanwhile, our strange universe just keeps getting stranger. ◼

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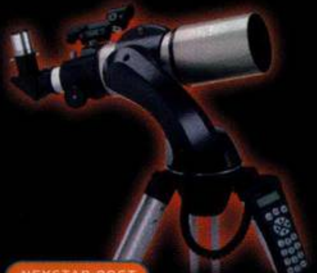

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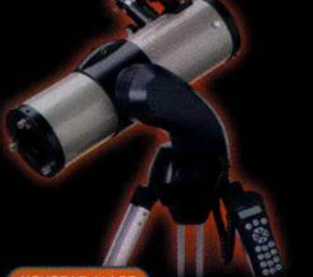

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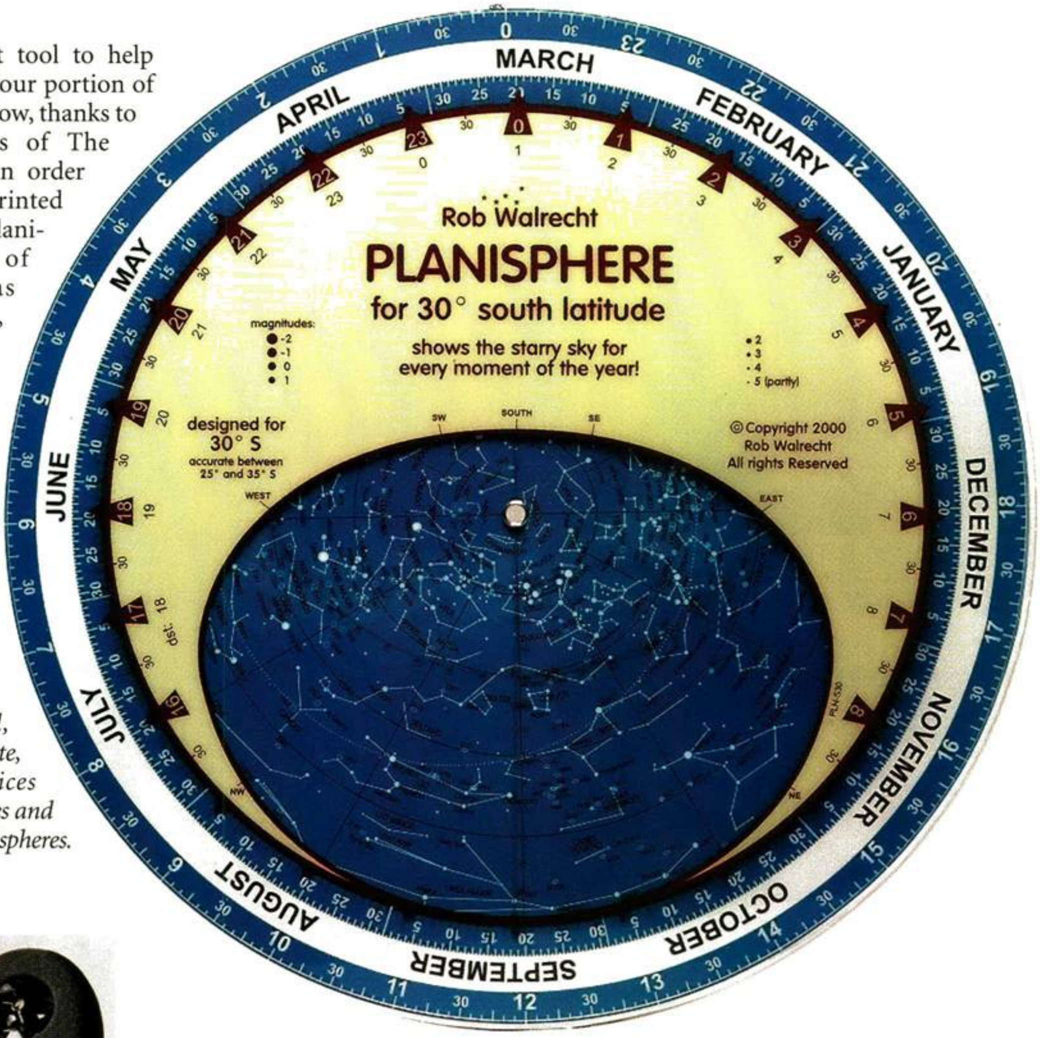
Prices vary according to quantity ordered, no matter how many different styles the customer chooses. Delivery takes about four weeks.

*Rob Walrecht Productions, Fuutstraat 6, 3815 JP Amersfoort, The Netherlands; phone/fax, (+31) 33-4755-543; e-mail, walrecht@globalxs.nl; website, http://www.walrecht.nl. Prices begin at about $5.00 (plus taxes and shipping) for orders of 100 planispheres.*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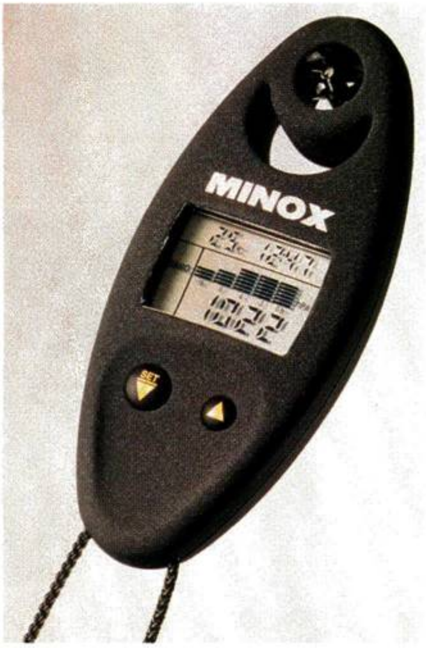

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*MINOX, 156 Ludlow Ave., Northvale, NJ 07647; phone, (201) 767-7500; fax, (201) 767-8666; e-mail, info@minox.com; website, http://www.minox.com.*

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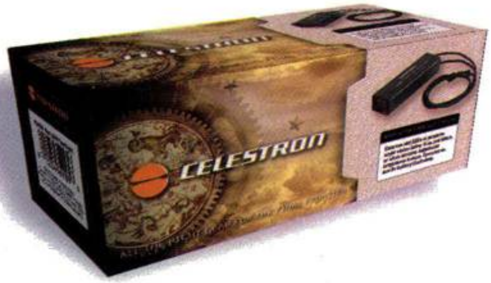

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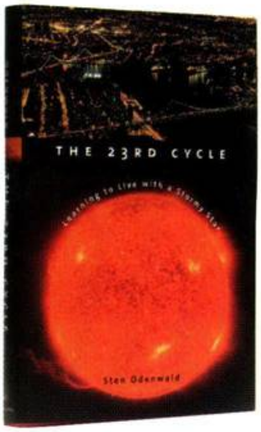
## A BOOKS



### The 23rd Cycle: Learning to Live with a Stormy Star

Sten Odenwald, 207 pages, Columbia University Press, New York, 2001; ISBN 0-231-12078-8; hardcover, $27.95.

▶ Earth is periodically wracked by storms from our nearest star, causing billions of dollars in damage and adversely affecting the lives of millions of people. The media downplay these events because powerful interests — such as satellite owners and power companies — stand to lose if the facts are more widely known.

So argues Sten Odenwald in *The 23rd Cycle: Learning to Live with a Stormy Star,* in what amounts to a whirlwind tour of the physics, history, and politics of the solar-activity cycle and its earthly consequences.

Although the sun is a rather ordinary star, it is anything but quiet. Convection in its outer layers forms magnetic fields that penetrate the surface and interact with the existing field, reversing the sun's overall magnetic polarity about every 11 years.

The reversal process induces titanic electrical currents in the corona. Occasionally, the sun produces flares, the largest explosions in the solar system, and coronal mass ejections, clouds of billions of tons of material hurling through interplanetary space at a million miles per hour.

When a coronal mass ejection impacts Earth, the effects include damage to commercial and military satellites, disruption of radio communication, increased radiation exposure to astronauts and airplane passengers, blackouts and damage to electrical power grids, and greatly accelerated corrosion of large structures, such as the Trans Alaska Pipeline System.

Odenwald discusses each of these major situations both historically and in a current-events context, which brings these ominous and vague effects down to Earth.

Well-timed for release during the current solar maximum, *The 23rd Cycle* is an accessible, entertaining, and technically accurate account of earthly events caused by solar activity. In three sections totaling 10 chapters, plus an index, references, and copious footnotes, Odenwald covers the most historic solar events of the 20th Century.

Along the way, he explains the solar and planetary physics that drive Earth's space weather, describes the past and current state of the electrical power and satellite industries, and speculates on the future effects of solar activity.

Disruption of radio communication is the most famous effect of solar activity. During World War II, D-Day preparations for the Normandy invasion included solar observations to discern whether sunspots might prevent units from communicating by radio. Today, these effects continue, periodically disrupting communications to remote outposts such as Antarctica and blocking radio links to airliners.

While the 1989 solar-storm-related Canadian blackout is familiar to solar physicists and informed amateurs, the details of the failure are fascinating and somewhat disturbing. Much less familiar and more disturbing are the many near-blackouts caused by solar storms during cycles 22 (in the late 1980s) and 23 (ongoing). Surprisingly, solar effects on power grids are not new: Odenwald cites examples as early as 1903.

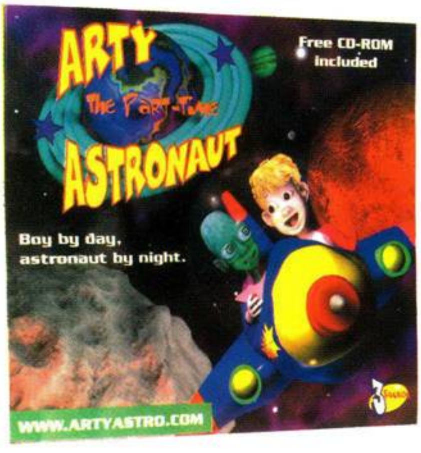
Likewise, many people are familiar with the January 11, 1997, failure of AT&T's Telstar 401 satellite that was caused by a large solar storm. The satellite was beaming signals for a number of big customers such as ABC, Fox, and PBS. AT&T was about to sell the satellite to Loral Space & Communications Ltd. when it malfunctioned.

A litany of other solar-related glitches and failures in commercial and NASA satellites and shuttle missions is less well-known to the general public. Odenwald's treatment includes a gripping account of the political motivators at play in the space industry, and he explains why solar effects are downplayed throughout the field.

Chock full of interesting and relevant facts, *The 23rd Cycle* should be required reading for solar physicists, congressional staffers, industrial magnates, and anyone who relies on electrical power, telephones, pagers, or global communications.

Fortunately, *The 23rd Cycle* is also engaging and pleasant to read. — *Craig DeForest, Southwest Research Institute, Boulder, Colorado*

## FIVE BOOKS FOR BEGINNERS



### Arty the Part-Time Astronaut

Eddie Carbin, 36 pages, 3 Pounds Press, Hayward, California, 2000; ISBN 0-9675299-0-5; paperback, $19.95.

▶ More a multimedia package than a book, *Arty the Part-Time Astronaut* includes the book and a CD-ROM that contains games, activities, and a link to www.artyastro.com — a website with games and activities for young, part-time astronauts.

In the book, Arty, our hero, helps his alien friend, Guplo, search for his lost family as the two fly through the solar system. Full-color computer-generated artwork fills the pages.

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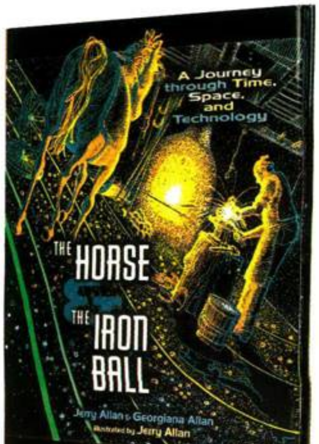
make information accessible without slowing down the story. However, the boxes are hard to distinguish from the story text and proved confusing for beginning readers.

And while the story itself did not engage my testers, they awarded good marks to the games and activities on the CD-ROM and website. The CD includes activities that allow users to have their weight and age computed on neighboring worlds. The website expands these activities with a time-zone computer.

(System Requirements: Windows 98/95/NT 4.0, Pentium 133 MHz or faster processor, 8 MB RAM, and a CD-ROM drive; Macintosh users must have system 7.5 or later, 32 MB of RAM, and a CD-ROM drive.) — *Kelly Quinn, educator/producer, Bishop Planetarium, South Florida Museum, Bradenton, Florida*


A Journey through Time, Space, and Technology
THE HORSE & THE IRON BALL
Jerry Allan & Georgiana Allan
Illustrated by Jerry Allan

### The Horse and the Iron Ball: A Journey through Time, Space, and Technology

Jerry Allan and Georgiana Allan, 48 pages, Lerner Publications Company, Minneapolis, Minnesota, 2001; ISBN 0-8225-2158-X, hardcover, $16.95.

▶ This beautiful picture book provides an astronomical explanation of what horses and iron balls have in common. Readers journey through cosmic time from the early universe through current astronomical theory as the connection between supernovae — the iron balls in the title — and horses is established.

The Allans walk us through the history of the solar system and the evolution of life on Earth. A chronological look at technology, beginning with the Iron Age through the era of horseshoes, "iron horses" (steam locomotives), automobiles, and ultimately space vehicles, provides a link to the formation of heavy elements created in supernova explosions. This background enhances our understanding of the processes that shape the universe.

Superb illustrations (including foldout timelines), thought-provoking questions, and original artwork make this book memorable.

For readers fascinated by theory and imaginative connections, *The Horse and the Iron Ball* offers a unique look at astronomical theory. — *K.Q.*

### See the Stars: Your First Guide to the Night Sky

Ken Croswell, 32 pages, Boyds Mills Press, Honesdale, Pennsylvania, 2000; ISBN 1-56397-757-5, hardcover, $16.95.

▶ Young sky watchers are in for a treat when they open Ken Croswell's latest book. *See the Stars* introduces readers to twelve of the most prominent constellations, so they look for a different one every month of the year.

See the Stars
YOUR FIRST GUIDE TO THE NIGHT SKY
KEN CROSWELL

This inviting book features full-page illustrations that depict each of the constellations and highlights the wonderful photography of Akira Fujii.

Readers will find a "Where and When to Look" box, a directional guide to finding each star pattern, and a wealth of interesting information about the constellations.

Croswell's enthusiasm permeates the book as he describes the special features within the constellations. His memorable treatment provides a lasting impression of star patterns.

Croswell also offers an introduction to skylore and a taste of astronomical theory that is sure to spark further interest in stargazing.

A flow chart at the back of *See the Stars* serves as an identification tool for planets and adds an informative final touch to this beginners' guide. — *K.Q.*

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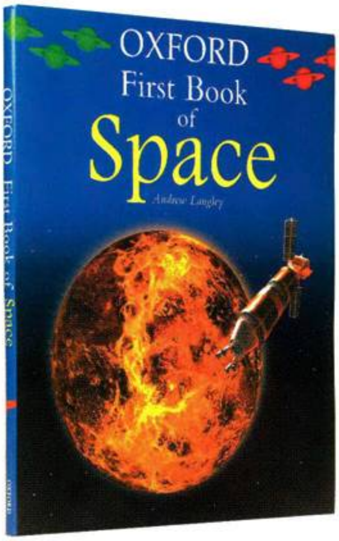

### Oxford First Book of Space

Andrew Langley, 48 pages, Oxford University Press, New York, 2000; ISBN 0-19-521686-5; hardcover, $18.95.

▶ The *Oxford First Book of Space* introduces the solar system and the universe to those aged 5 to 10 years. The eye-catching illustrations should appeal to explorers just beginning their investigation of the universe. A fact file at the end of the book will impress readers who would like to have important facts readily available for school projects and science reports.

Unfortunately, factual errors in the text and incomplete explanations mar the book's ability to engage young readers or serve as a reference for further learning. — *K.Q.*

### Our Earth and the Solar System

Ken Graun, 36 pages, Ken Press, Tucson, Arizona, 2001; ISBN 1-928771-02-5; hardcover, $15.95.

▶ The first of four books in the 21st Century Astronomy Series, this volume offers a comprehensive introduction to the solar system. The sun, planets, the moon, the Main Asteroid Belt, and comets are covered in a lavish, double-page spread. Illustrations complement the text, which is full of facts that will delight budding planetary explorers.

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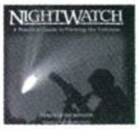

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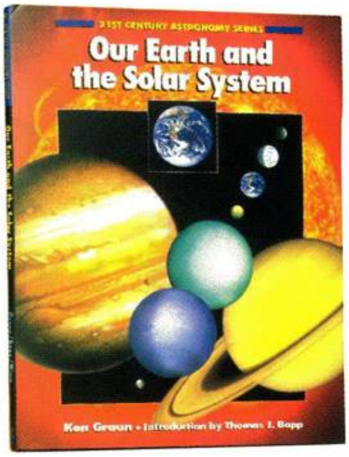
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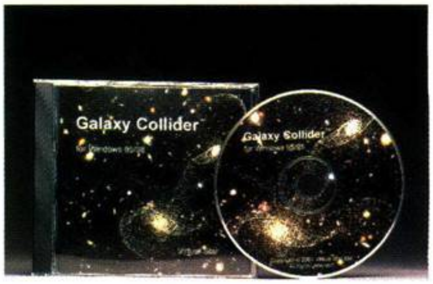

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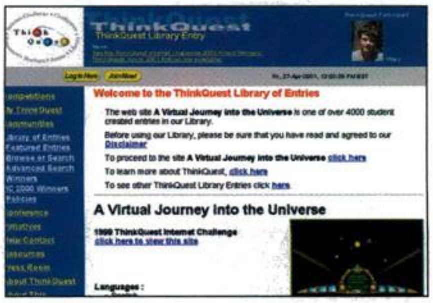
## A THE WEBWEAVER

*by Richard J. Bartlett*

▶ If you haven't acquainted yourself with Neptune and its slightly larger twin, Uranus, July and August are the months to do it. Neptune reaches opposition — when it lies opposite the sun in the sky — on July 30; Uranus follows suit on August 15.



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Another site, *Views of the Solar System* (http://www.solarviews.com) has facts and figures, but also rather boring, text-heavy pages. Unfortunately, neither site offers observation tips or finder charts. A

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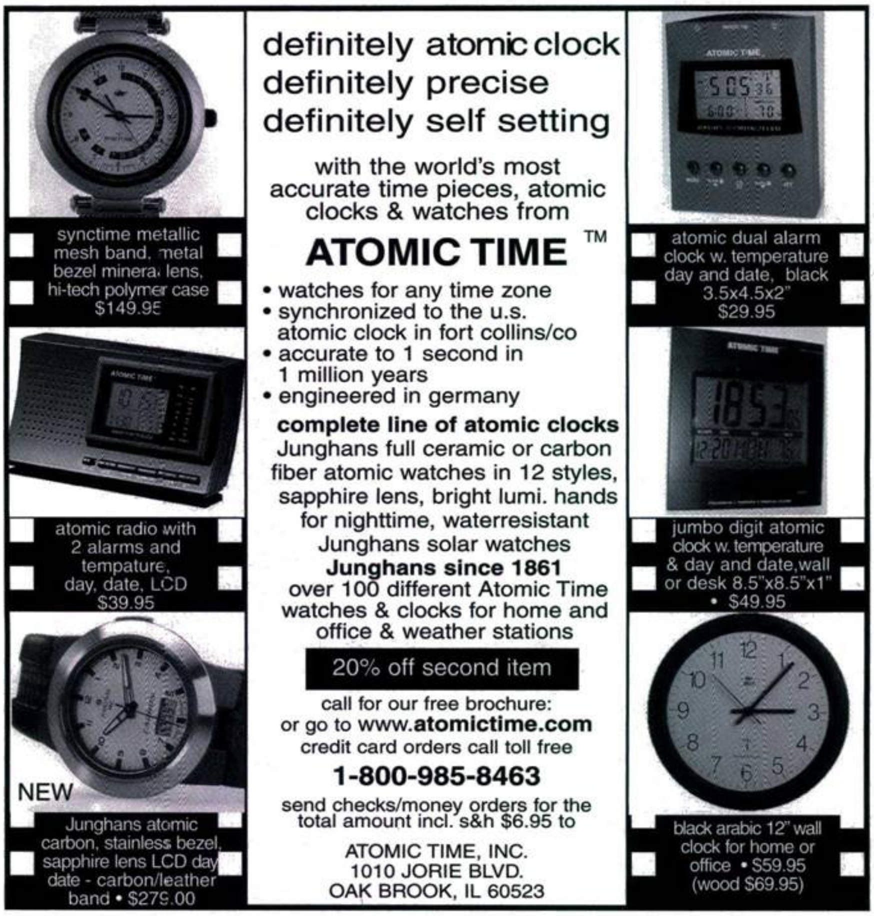
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Frank Zullo

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Ralph A. Worley Observatory, south of Shreveport, Louisiana. Contact Cran Lucas, (318) 797–1524; website, http://www. lsus.edu/nonprofit/sbas/.

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Ochoco National Forest, Oregon. Contact the Oregon Star Party, 16016 S.E. Division, PMB 307, Portland, OR 97236; hotline, (503) 306–2992; website, http://oregonstarparty.org.

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Breezy Hill, Springfield, Vermont. Contact Stellafane Convention, Springfield Telescope Makers, P.O. Box 601, Springfield, VT 05156; website, http://www.stellafane.com.

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Torquay Boys Grammar School, Devon, England. Contact John Parratt, 73 Woodbarn Lawn, Whiddon Valley, Barnstaple, North Devon EX32 8PQ; website, www.torbayastro.org.uk.

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Bruneau Dunes State Park, Bruneau, Idaho. Contact the Boise Astronomical Society, P.O. Box 8386, Boise, ID 83707; or Mike Blackburn, (208) 375–8850; website, http://www.boiseastro.org.

AUGUST 17–19

### Northwoods Starfest

Hobbs Observatory, Fall Creek, Wisconsin. Contact Bert Moritz, (715) 835–4034; website, www.cvastro.org.

AUGUST 17–19

### Saskatchewan Summer Star Party

Cypress Hills Interprovincial Park,

Saskatchewan, Canada. For more information, contact Ellen Dickson, 11-103 Powe Street, Saskatoon, SK, S7N 1W5, Canada; (306) 249–1091; website, http://prana.usask.ca/~rasc/sssp01.html.

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### Star Party in the Bernese Alps
Gurnigel Pass, Switzerland. Contact Radek Chromik, Schaufelweg 109, CH-3098 Schliern bei Koniz, Switzerland; website, http://www.starparty.ch/english.html

AUGUST 18
### Lake Whitney Summer Star Party
Lake Whitney State Park, Texas. Contact Thomas Williamson, 7005 Southampton, North Richland Hills, TX 76180; (817) 656–0901.

AUGUST 18
### Night Skies at Mesa Verde
Mesa Verde National Park, Colorado. Contact Brian Brusa, (800) 791–4014; website, www.visitmesaverde.com.

AUGUST 18–25
### Mt. Kobau Star Party
Osoyoos, British Columbia, Canada. Contact Guy Mackie, Box 20119 TCM, Kelowna, BC, V1Y 9H2; (250) 861–3074; website, http://www.bcinternet.com/~mksp.

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### Astro-Atlantik
Mount Carleton Provincial Park, Shippagan, New Brunswick, Canada. Contact Jacques Robichaud, 177 rue Bellefeuille, Shippagan, NB, E8S 1G5; (506) 336–8085. A

**CONTACT**

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or to tconley@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

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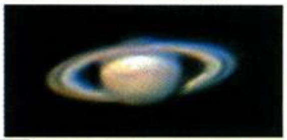

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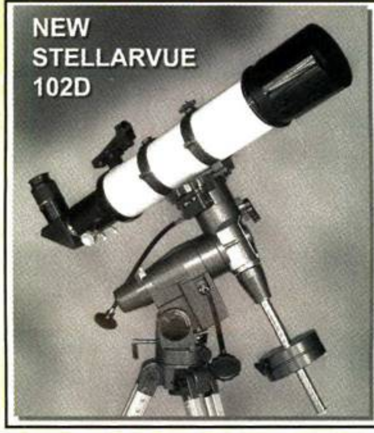

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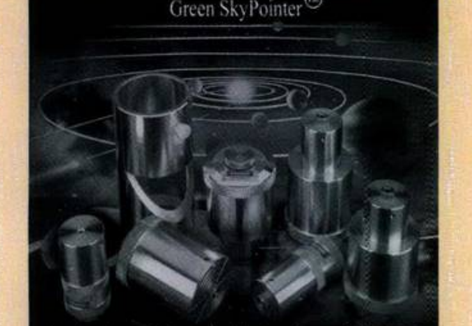

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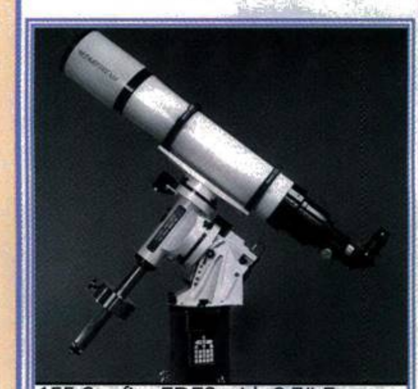

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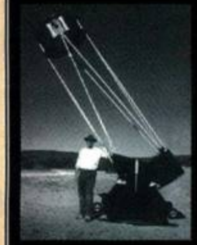

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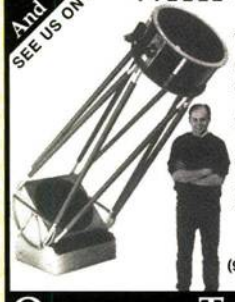

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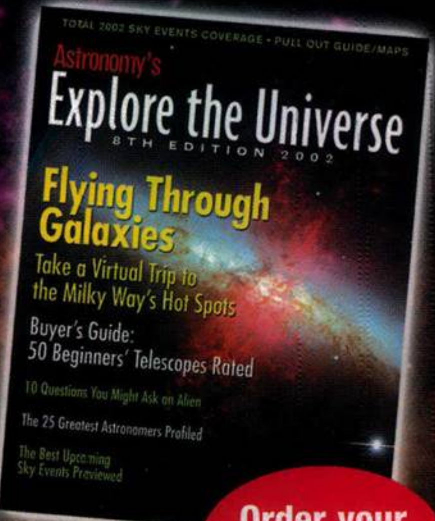
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## ANNOUNCEMENTS/OPPORTUNITIES

**Midwest Birding Symposium 2001** is winging its way to Wisconsin! Mark your calendars now for the 2001 Midwest Birding Symposium (MBS). Thursday, August 30 through Sunday, September 2, 2001. Hosted by BIRDER'S WORLD Magazine, EAGLE OPTICS, & the WISCONSIN SOCIETY FOR ORNITHOLOGY. The symposium will offer a varied menu of speakers and field trips of the state, Green Bay is surrounded by wetlands that vary from Lake Michigan shoreline to cattail marsh and sedge meadow. Speakers include John Acorn, George Archibald, Kenn Kaufman, Arthur Morris, Peter Stangel and more. The symposium will be held at the Regency Suites Hotel and KI Conference Center in downtown Green Bay. For accommodations, call (800) 236-3330. Sponsors include Swift Instruments, Leica Sports Optics, Swarovski Optics, Kaytee Products, Wild Birds Unlimited, National Fish & Wildlife Foundation, WI Dept. of Natural Resources, US Fish & Wildlife Service, the Green Bay Area Visitor & Convention Bureau, Friends of Bay Beach Wildlife Sancturary, and Mosquito Hill Nature Center. Additional information can be found on the BIRDER'S WORLD Web site: www.birdersworld.com. For questions or registration, please contact Jenny Birkel at (800) 558-1544 ext. 245; or e-mail at jbirkel@kalmbach.com.

## SOFTWARE FOR SALE

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## TELESCOPES FOR SALE

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**Used Telescopes:** Takahashi, Pentax, Vixen. Flutes, Ukiyoe Prints. http://www.net0726.ne.jp/~jhniemi

## NEXT month in Astronomy

NASA/JPL

### DIRTY SNOWBALL PROBE

Comets may relinquish some well-kept secrets when Deep Space 1 visits Comet Borrelly.

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*NEW ENDEAVORS*

# Night Vision

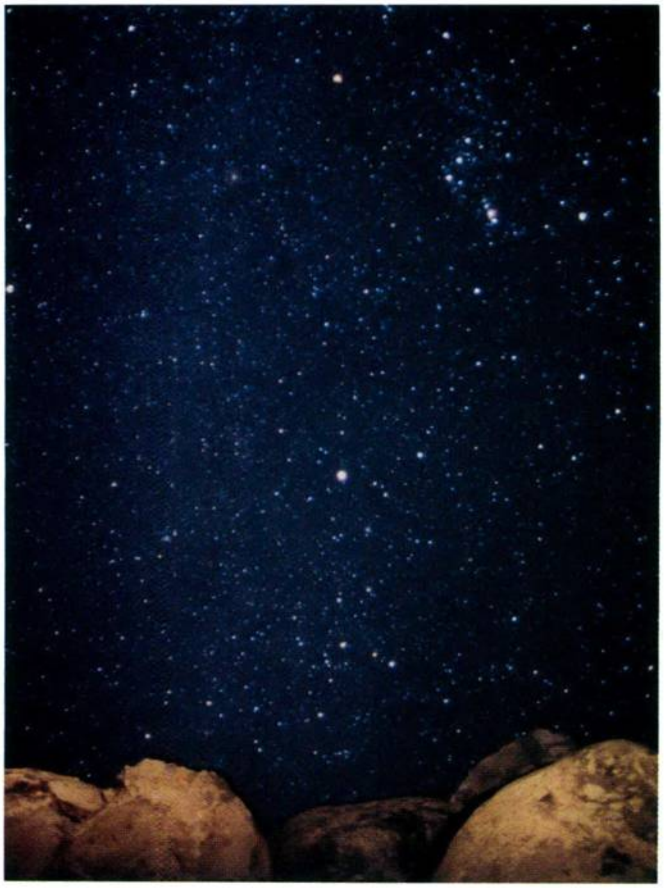
BY GLEN HACKER

▶Living in a city of 100,000 people, with a street light approximately 100 feet away from my backyard, I usually do not experience good seeing conditions from my home. But recently I read an article on an intensifier eyepiece that claimed to improve the view through a telescope by two magnitudes.Was it too good to be true? By coincidence, I discovered a used first-generation monocular at a local store for $115; I didn't even think twice before buying it. Now all I had to do was wait for nightfall.

That night arrived dark and clear. A bit skeptical, I ventured into the yard and turned on the monocular. To my surprise, it was even better than I had expected; the stars seemed to pop out of the sky right at me.

Intrigued, I decided to go a step further, and make my own "night vision" telescope. I figured I needed a second-generation tube for a clear view from edge to edge. I also needed to make a unit that would allow me to mount my lens and camera. I found a new PVS-4 mm intensifier tube. A trip to the hardware store and four or five attempts later, I was ready.

On the next clear night, I pointed the unit to the stars, using an 80mm to 200mm zoom lens. I couldn't believe my eyes. The stars looked more gorgeous than ever before. While the first-generation was only clear in the center of view, the second was clear nearly all the way across the field of view. I



**Rising Moon, Jupiter, Saturn, Aldebaran, and Plaides**

**JOHN MCNEAL**

(400mm lens at f/1.4, taken near Pompeys Pillar, Montana)

**Milky Way over Anza Borrego Desert, California**

**JERRY SCHAD**

(24mm lens at f/1.7, two-minute exposure) was so thrilled that I decided to take another leap–pictures.

After making an adapter for a digital camera, I headed out on the next night ready to make my first attempt at astrophotography with my "night vision" lens. I turned on the intensifier and focused the unit on a star—it looked unbelievable. I excitedly took several pictures, then hurried to my laptop to download the pictures. To my dismay, the first group of pictures weren't just bad—they were terrible! But instead of getting discouraged, I took note of all of the mistakes I had made, and prepared to try again.

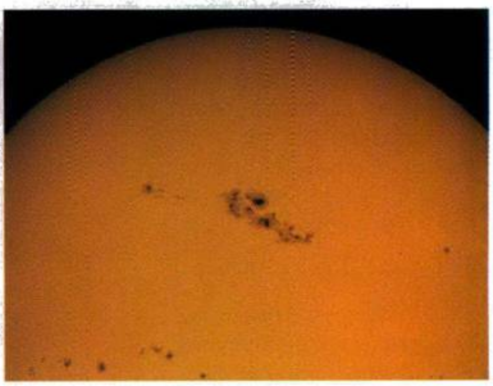
The following night, I was armed with a tripod and used the 10-second self-timer on the camera, instead of snapping the pictures manually. This time, I discovered that the zoom turned easily, causing half of the pictures to appear out of focus. But to my delight, the other half of the pictures, taken of Orion, were fabulous.

Encouraged by my semi-success, I headed out the next night with a 300mm fixed-focus lens, and took about 20 more pictures of Orion and the Pleiades. I was thrilled to find that all were in focus. On my next observing night, I ventured away from the city lights, and drove to Pulpit Rock Mountain, near Allentown, Pennsylvania. I took a total of 89 pictures with my 300mm lens. Although some didn't turn out, the rest looked great. And, after matching the Pleiades picture to a star chart, I found that, thanks to the intensifier, I was able to get two magnitudes past the 10-

**"Night Vision" View of Orion**

GLEN HACKER

(300mm fixed lens with intensifier tube)



**Sunspots**

PETER ROTH

(70mm achromatic refractor, Baader filter, 100 ISO Fuji Superia film, taken March 28, 2001)

**Star Trails over Baja California, Mexico**

GERARDO RAMOS LARIOS

(50mm lens at f/2.8, Kodak T-Max 100 film, 90-minute exposure)

magnitude limit on the 300mm lens.

Finally, I have learned how to take beautiful pictures with my night-vision intensifier. But I'm not stopping there; now, I'm hoping to buy a bigger telescope, for even better photos. ◼

---

*Glen Hacker, of Allentown, Pennsylvania, has been an avid amateur astronomer for more than forty years.*

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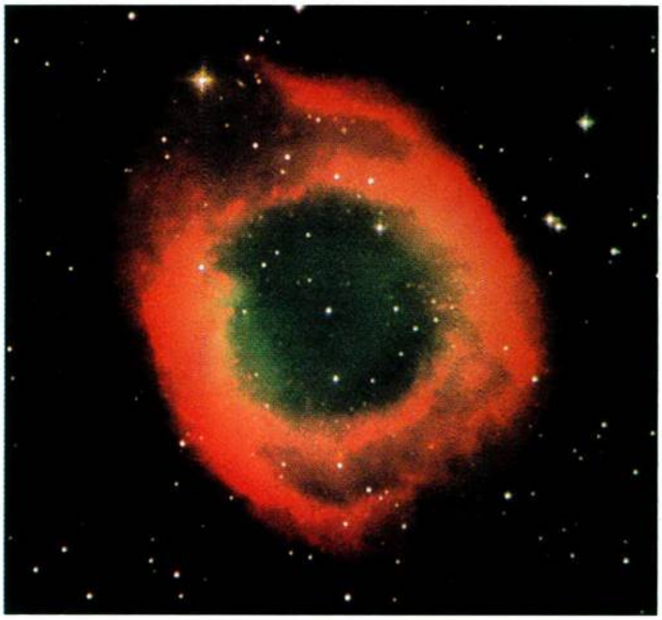
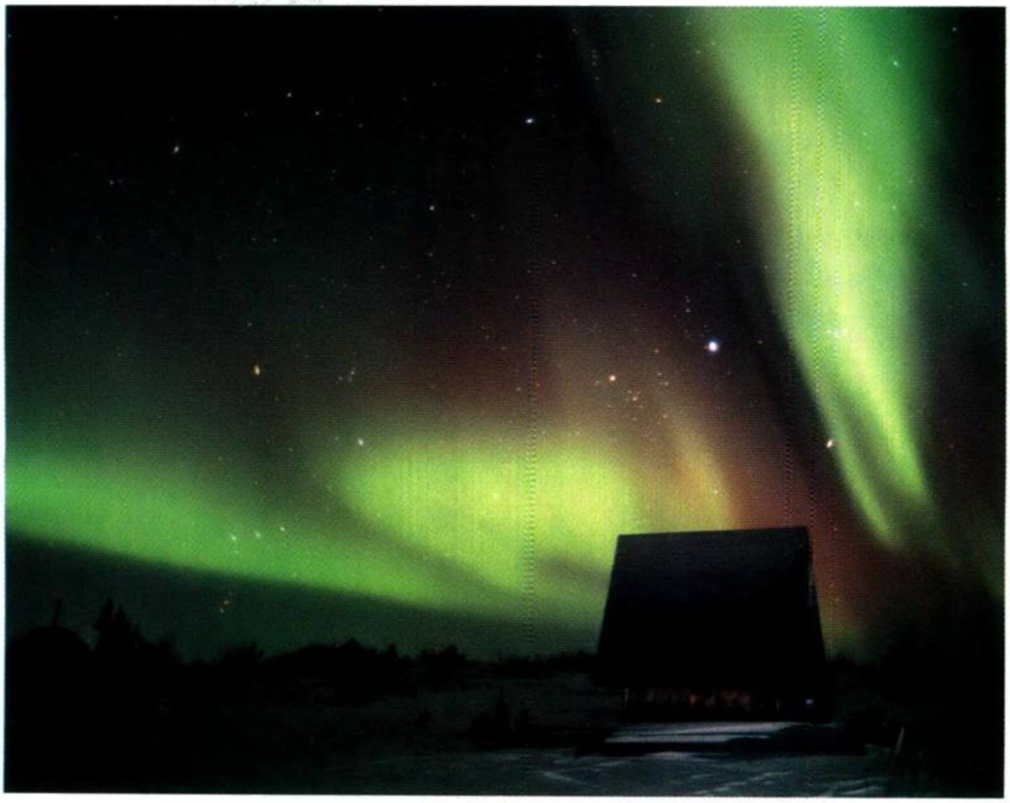


**Helix Nebula, NGC 7293**

CLIFF WRIGHT

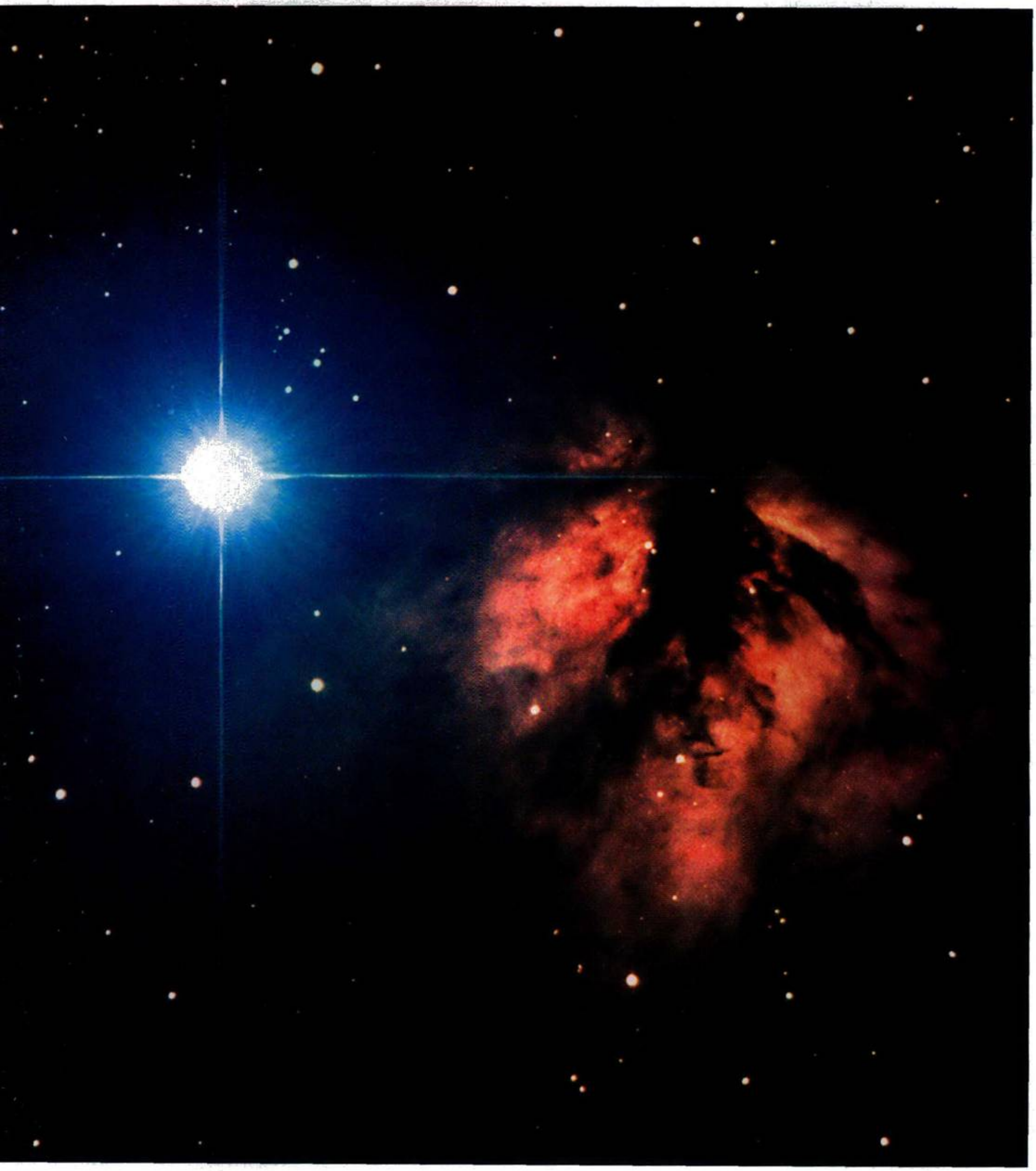
(18.2-inch f/2.8 SCT, ST8E CCD camera, CFW8 color filter wheel, composite of two exposures)



**Aurora near Fairbanks, Alaska**

MICHAEL J. O'LEARY

(24mm lens at f/2, Fuji 800 Superia film, taken March 19, 2001)

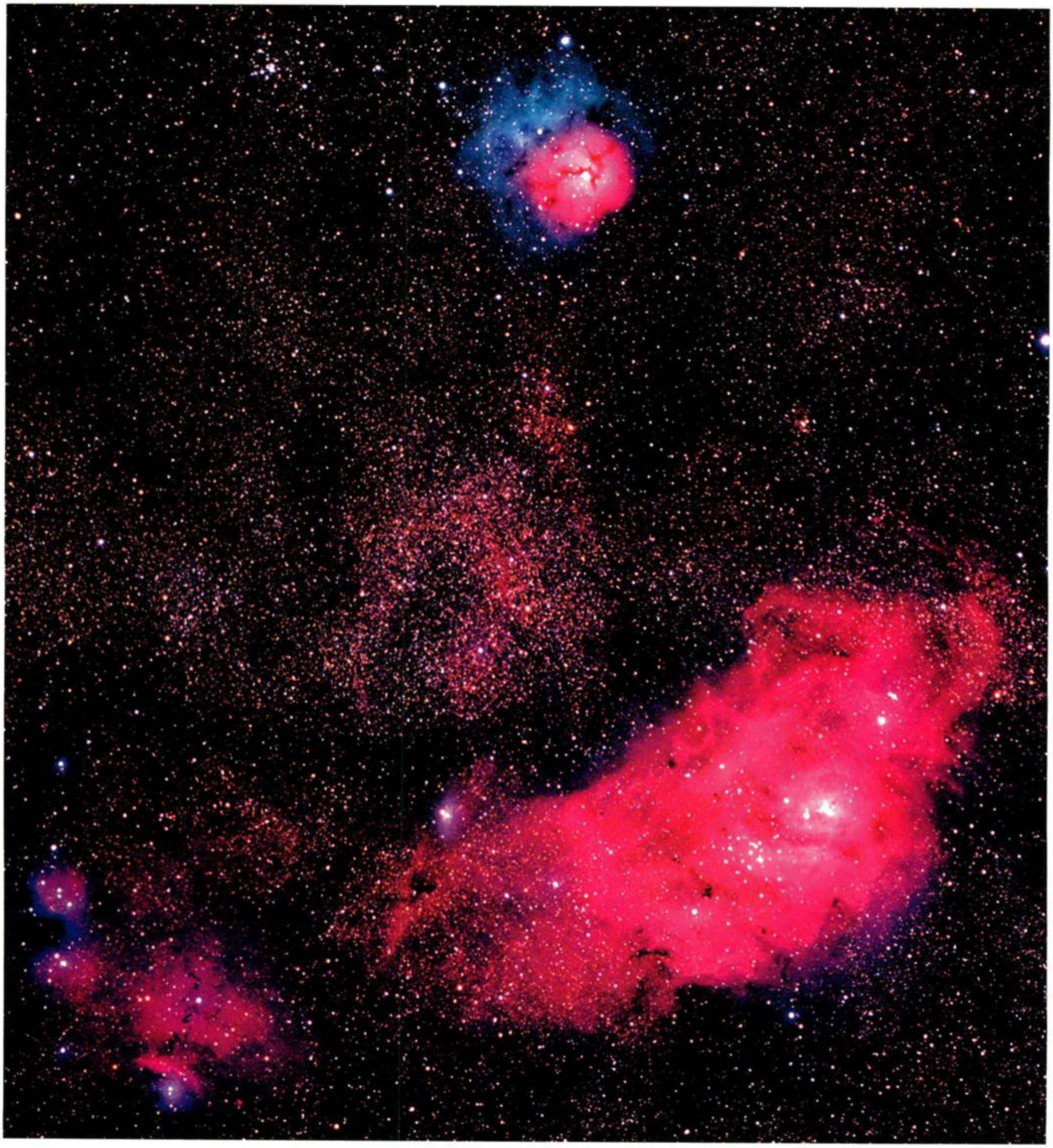


**Flame Nebula and Alnitak**

**BOBBY MIDDLETON**

(12.5-inch SCT at f/7, hypered Kodak PJ 400 film, composite of two 60-minute exposures)

*This month's best astrophoto*



**Field of the Lagoon and Trifid Nebulae, M8 and M20**

GEORGE GREANEY

(6-inch f/7 refractor, hypered Kodak 120 PPF film, composite of three 30-minute exposures)

The Lagoon and Trifid represent the densest areas of hydrogen gas in the Sagittarius star cloud, and are busy producing infant stars as their gas and dust coelesces.

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# LX90

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* Patent pending

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